LAND COVER CLASSIFICATION SYSTEM

LCCS

CLASSIFICATION CONCEPTS AND USER MANUAL

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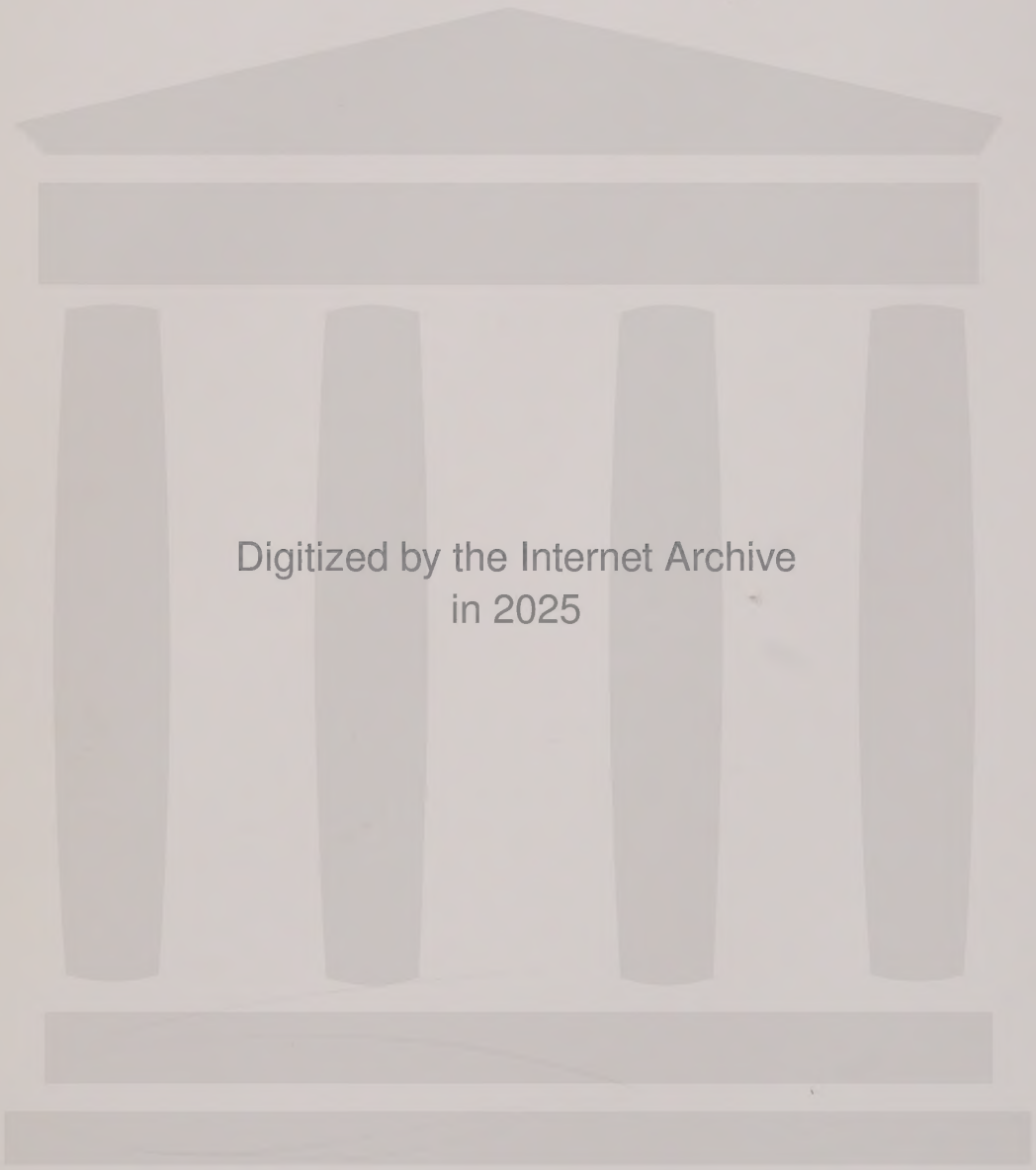

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LAND COVER CLASSIFICATION SYSTEM

LCCS

CLASSIFICATION CONCEPTS AND USER MANUAL

FOR SOFTWARE

VERSION 1.0

By

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FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS

Rome, 2000

The conclusions given in this report are considered appropriate at the time of its preparation. They may be modified in the light of further knowledge gained at subsequent stages of the project

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SUMMARY

The Land Cover Classification System (LCCS) is a comprehensive, standardized *a priori* classification system, designed to meet specific user requirements, and created for mapping exercises, independent of the scale or means used to map. Any land cover identified anywhere in the world can be readily accommodated. The classification uses a set of independent diagnostic criteria that allow correlation with existing classifications and legends.

Land cover classes are defined by a combination of a set of independent diagnostic criteria – the so-called classifiers – that are hierarchically arranged to assure a high degree of geographical accuracy. Because of the heterogeneity of land cover, the same set of classifiers cannot be used to define all land cover types. The hierarchical structure of the classifiers may differ from one land cover type to another. Therefore, the classification has two main phases:

- an initial *Dichotomous Phase*, where eight major land cover types are distinguished; and
- a subsequent *Modular-Hierarchical Phase* where the set of classifiers and their hierarchical arrangement are tailored to the major land cover type.

This approach allows the use of the most appropriate classifiers and reduces the total number of impractical combinations of classifiers. Because of the complexity of the classification and the need for standardization, a software application has been developed to assist the interpretation process. This will reduce heterogeneity between interpreters and between interpretations over time. Because of the flexible manner in which the classification is set up, with creation of classes at different levels of the system and the optional use of modifiers, environmental attributes and specific technical attributes in combination, coupled with the tremendous number of classes possible, this innovative software application assists the user to select the appropriate class using a step-by-step process, i.e., classifier by classifier. The software application will be available both as a stand-alone product and integrated into a digital image interpretation software suite which will allow interpretation of imagery followed by labelling of the mapping units with the land cover classes, the Africover Interpretation and Mapping System (AIMS).

The classification system leads to mutually exclusive land cover classes, which comprise: (1) a unique Boolean formula (a coded string of classifiers used); (2) a standard name; and (3) a unique numerical code. Both the numerical code and standard name can be used to build an automatically generated Legend, with the classes created grouped according to the main land cover categories and their domains according to the level of detail. The nomenclature can be linked to a user-defined name in any language.

Further definition of the Land Cover Class can be achieved by adding attributes. Two types of attributes, which form separate levels in the classification, are distinguished:

- *Environmental Attributes*: these are attributes (e.g., climate, landform, altitude, soil, lithology and erosion) which influence land cover but are not inherent features of it and should not be mixed with "pure" land cover classifiers; and

- *Specific Technical Attributes*: these are associated with specific technical disciplines (e.g., for (Semi-)Natural Vegetation, the Floristic Aspect can be added; for Cultivated Areas, the Crop Type; and for Bare Soil, the Soil Type).

All *Primarily Vegetated* land cover classes are derived from a consistent physiognomic-structural conceptual approach that combines the classifiers *Life Form, Cover* and *Height* (in (Semi)Natural Vegetation) and *Life Form* (in Cultivated Areas) with *Spatial Distribution*. The *Primarily Non-Vegetated* classes have a similar approach, using classifiers that deal with surface aspects, distribution/density and height/depth.

The advantages of the classifier, or parametric, approach are manifold. The system created is a highly flexible *a priori* land cover classification in which each land cover class is clearly and systematically defined, thus providing internal consistency. The system is truly hierarchical and applicable at a variety of scales. Re-arrangement of the classes based on re-grouping of the classifiers used facilitates extensive use of the outputs by a wide variety of end-users. Accuracy assessment of the end product can be generated by class or by the individual classifiers forming the class. All land covers can be accommodated in this highly flexible system; the classification could therefore serve as a universally applicable reference base for land cover, thus contributing towards data harmonization and standardization.

Keywords:
land cover, classification, classification system, standardization, harmonization.

ACKNOWLEDGEMENTS

The Land Cover Classification System (LCCS) is the result of an initiative to take a first step towards an internationally agreed reference base for land cover. The objectives of the Africover Programme of the Environment and Natural Resources Service (SDRN), FAO, are to develop an approach for conceptualizing, defining and classifying land cover that coincides with the FAO/UNEP initiative on harmonization of land cover and land use classifications. The first full operational version of the classification system and software application has been developed for implementation by the first project to use this classification system, the Government of Italy Trust Fund project GCP/RAF/287/ITA *Africover - East Africa Project* in collaboration with the Environment and Natural Resources Service (SDRN) and the Land and Water Plant Nutrition Management Service of FAO.

These land cover classification concepts were discussed and endorsed at the meeting of the international *Working Group on Classification and Legend* (Senegal, July 1996) supported by Government of France Trust Fund GCP/RAF/311/FRA (FAO, 1997).

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Antonio Di Gregorio and Louisa J.M. Jansen

July 2000

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– PART A –

Land Cover Classification System: A Dichotomous, Modular-Hierarchical Approach

Classification Concepts

INTRODUCTION

Classification is easy:
it is something you just do.
F.C. Bawden

A fool sees not the same tree
that a wise man sees.
W. Blake, *Marriage of Heaven and Hell*

The main resource controlling primary productivity for terrestrial ecosystems can be defined in terms of land: the area of land available, land quality and the soil moisture characteristics. Despite successful substitution of land-based resources with fossil fuels and mineral resources, land remains of prime importance (Darwin *et al.*, 1996). Land cover and land use represent the integrating elements of the resource base. Changes in land cover and land use affect the global systems (e.g., atmosphere, climate and sea level) or they occur in a localized fashion in enough places to add up to a significant total (Meyer and Turner, 1992). Land cover is the expression of human activities and as such changes with alterations in these. Hence, land cover is a geographical feature which may form a reference base for applications ranging from forest and rangeland monitoring, production of statistics, planning, investment, biodiversity, climate change, to desertification control.

People have reshaped the earth continually but the present magnitude and rate are unprecedented. Nowadays it is realized that it is very important to know how land cover has changed over time, in order to make assessments of the changes one could expect in the (near) future and the impact these changes will have on peoples' lives. As people are the main users of the land, it is important for any system to be oriented towards them.

Due to the lack of appropriate land cover data, many assessments have used models to delimit potential land cover (e.g., Alexandratos, 1995). Although the use of potential land cover is important in modelling simulated future scenarios, there are major limitations. Information describing current land cover is an important input for planning and modelling, but the quality of such data defines the reliability of the simulation outputs (Townshend, 1992; Belward, 1996).

In addition to a high demand for improved land cover data sets because of an increasing need to be able to precisely describe and classify land cover in order to develop sustainable land use systems, there is also a growing need for standardization and compatibility between data sets and for the possibility to map, evaluate and monitor wide areas (Di Gregorio, 1991, Reichert and Di Gregorio, 1995; Thompson, 1996; FAO, 1995 and 1997). Technical advances, such as the vast amount of remote sensing data that has become available from earth observation satellites, makes this increasingly possible (Di Gregorio, 1995).

In 1993, UNEP and FAO organized a meeting to catalyse co-ordinated action towards harmonization of data collection and management and to take a first step towards an internationally agreed reference base for land cover and land use (UNEP/FAO, 1994). The Africover Programme of the Environment and Natural Resources Service (SDRN), which intends to map land cover for the whole of Africa, needed a land cover reference system for operational use.

The objectives of the Africover Programme are to:

- respond to the need for land cover data of a variety of end-users;
- apply the methodology in mapping exercises, independent of the means used, which may range from high resolution satellite imagery to aerial photography;
- link with existing classifications and legends, allowing comparison and correlation; and
- support, to the extent possible, international ongoing initiatives on classification and definition of land cover.

The main objective of the initiative for definition of a reference classification is to respond to the need for standardization (or harmonized collection of data, as mentioned in UNCED's Agenda 21 Chapter 10, for which FAO is Task Manager within the UN system) and to develop a common integrated approach to all aspects of land cover. This implies a methodology that is applicable at any scale, and which is comprehensive in the sense that any land cover identified anywhere in the world can be readily accommodated.

Existing published classifications and legends, as well as nomenclatures, were analysed (Danserau, 1961; Fosberg, 1961; Eiten, 1968; UNESCO, 1973; Mueller-Dombois and Ellenberg, 1974; Anderson *et al.*, 1976; Kuechler and Zonneveld, 1988; CEC, 1993; UNEP/FAO, 1994; Duhamel, 1995; Beek, De Bie and Driessen, 1997), together with relevant FAO documents (Nègre, 1995; Barisano, 1996; Wyatt *et al.*, unpubl.).

The initial concepts of the classification were discussed by the international Africover Working Group on Classification and Legend (Senegal, July 1996) (Di Gregorio and Jansen, 1996c; FAO, 1997). While fully developing the system, links with other international ongoing activities on classification of land cover were developed, such as the U.S. Federal Geographic Data Committee (FGDC) - Vegetation Subcommittee and Earth Cover Working Group (ECWG); the South African National Land Cover Database Project (Thompson, 1996); and the International Geosphere-Biosphere Programme (IGBP) - Data and Information System (DIS) Land Cover Working Group and Land Use and Land Cover Change (LUCC) Core Project. The first full operational version of the classification and software application has been developed by the GCP/RAF/287/ITA *Africover - East Africa* project.

The approach developed for land cover could serve as the basis for a reference classification system with links to specific expertise, because it describes and allows correlation of land cover with a set of independent diagnostic criteria, the so-called classifiers, rather than being nomenclature based. Also, existing classifications and legends can be "translated" into the reference system, thus facilitating the use of existing historical materials. Re-arrangement of the classes, based on re-grouping of the used classifiers, facilitates the extensive use of the outputs by a wide variety of end-users.

1. DEFINITIONS

1.1 LAND COVER

The definition of land cover is fundamental, because in many existing classifications and legends it is confused with land use. It is defined as:

Land cover is the observed (bio)physical cover on the earth's surface.

When considering land cover in a very pure and strict sense it should be confined to describe vegetation and man-made features. Consequently, areas where the surface consists of bare rock or bare soil are describing *land* itself rather than land *cover*. Also, it is disputable whether water surfaces are real land cover. However, in practise, the scientific community usually describes those aspects under the term land cover.

Land use is characterized by *the arrangements, activities and inputs people undertake in a certain land cover type to produce, change or maintain it.* Definition of land use in this way establishes a direct link between land cover and the actions of people in their environment.

The following examples are a further illustration of the above definitions:

- "grassland" is a cover term, while "rangeland" or "tennis court" refer to the use of a grass cover; and
- "recreation area" is a land use term that may be applicable to different land cover types: for instance sandy surfaces like a beach; a built-up area like a pleasure park; woodlands; etc.

1.2 CLASSIFICATION AND LEGEND

Classification is an abstract representation of the situation in the field using well-defined diagnostic criteria: the classifiers (Figures 1 and 2). Sokal (1974) defined it as: "the ordering or arrangement of objects into groups or sets on the basis of their relationships." A classification describes the systematic framework with the names of the classes and the criteria used to distinguish them, and the relation between classes. Classification thus necessarily involves definition of class boundaries that should be clear, precise, possibly quantitative, and based upon objective criteria.

A classification should therefore be:

- *Scale independent,* meaning that the classes at all levels of the system should be applicable at any scale or level of detail; and
- *Source independent,* implying that it is independent of the means used to collect information, whether satellite imagery, aerial photography, field survey or some combination of them is used.

A *legend* is the application of a classification in a specific area using a defined mapping scale and specific data set (Figure 3). Therefore a legend may contain only a proportion, or sub-set, of all possible classes of the classification. Thus, a legend is:

- *Scale and cartographic representation dependent* (e.g., occurrence of mixed mapping units if the elements composing this unit are too small to be delineated independently); and
- *Data and mapping methodology dependent* (e.g., an aerial photograph shows different features compared to a satellite false colour composite image).

FIGURE 1.
Abstract presentation of a classification consisting of a continuum with two gradients: circles and triangles in red and white representing the concrete situation in the field – Figure 2 - (From Kuechler and Zonneveld, 1988).

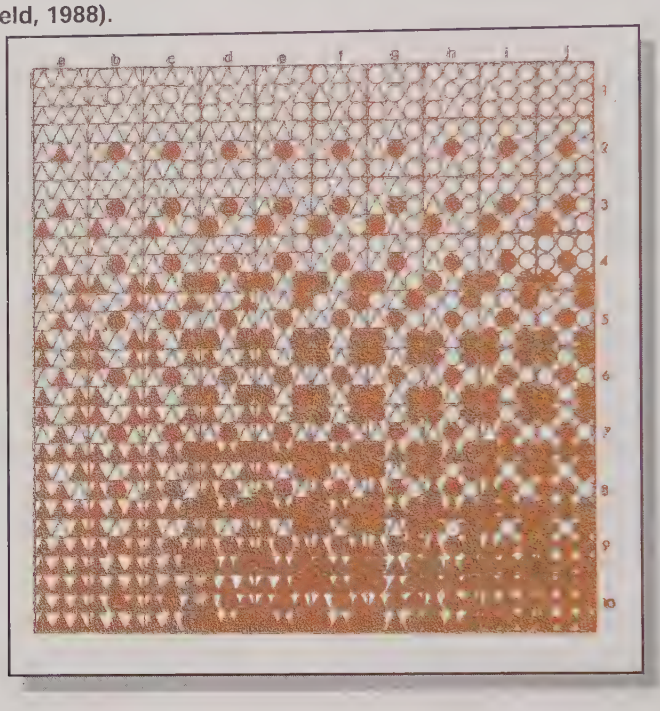


FIGURE 2.
Concrete situation in the field in a particular area (From Kuechler and Zonneveld, 1988).

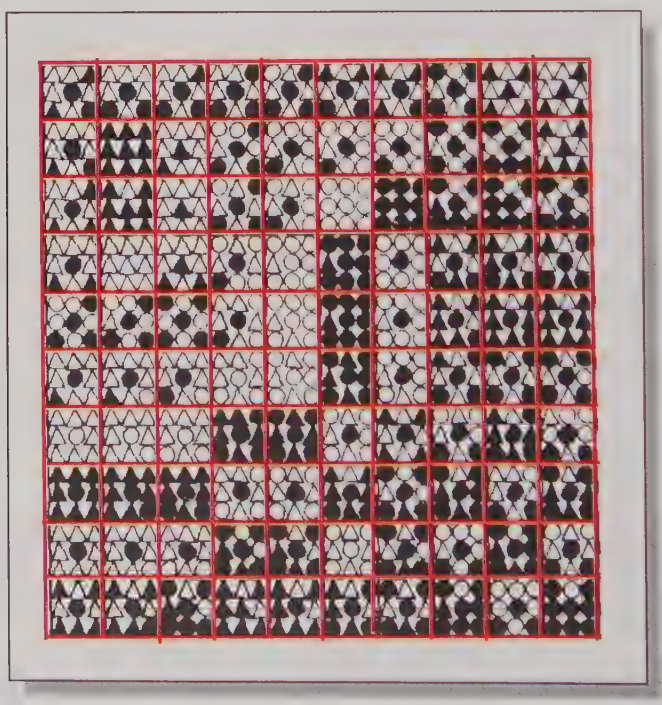
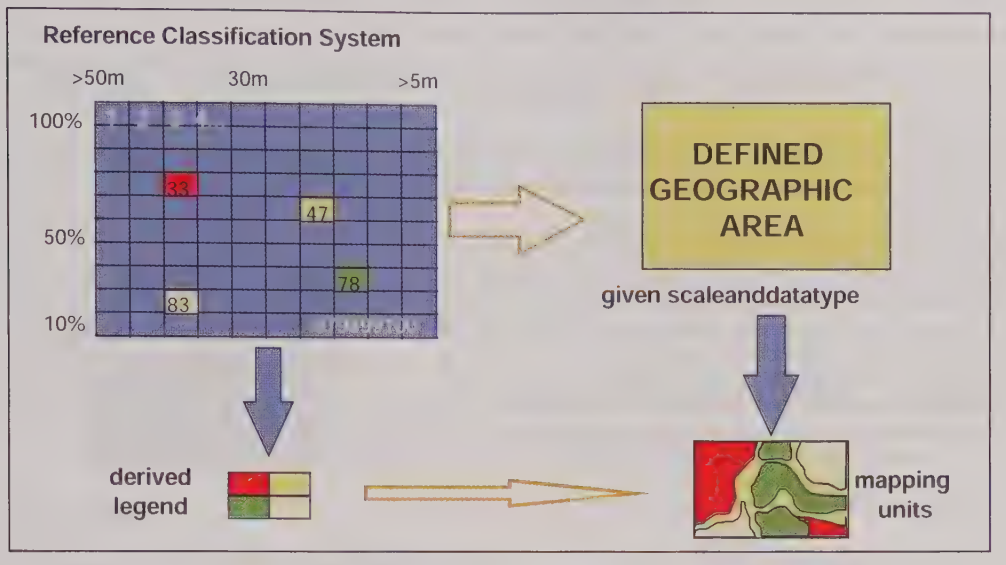


FIGURE 3.
Legend as application of a classification in a particular area.



1.3 HIERARCHICAL VERSUS NON-HIERARCHICAL SYSTEMS

Classification systems come in two basic formats, *hierarchical* and *non-hierarchical*. Most systems are hierarchically structured because such a classification offers more consistency owing to its ability to accommodate different levels of information, starting with structured broad-level classes, which allow further systematic subdivision into more detailed sub-classes. At each level the defined classes are mutually exclusive. At the higher levels of the classification system few diagnostic criteria are used, whereas at the lower levels the number of diagnostic criteria increases. Criteria used at one level of the classification should not be repeated at another, i.e., lower, level.

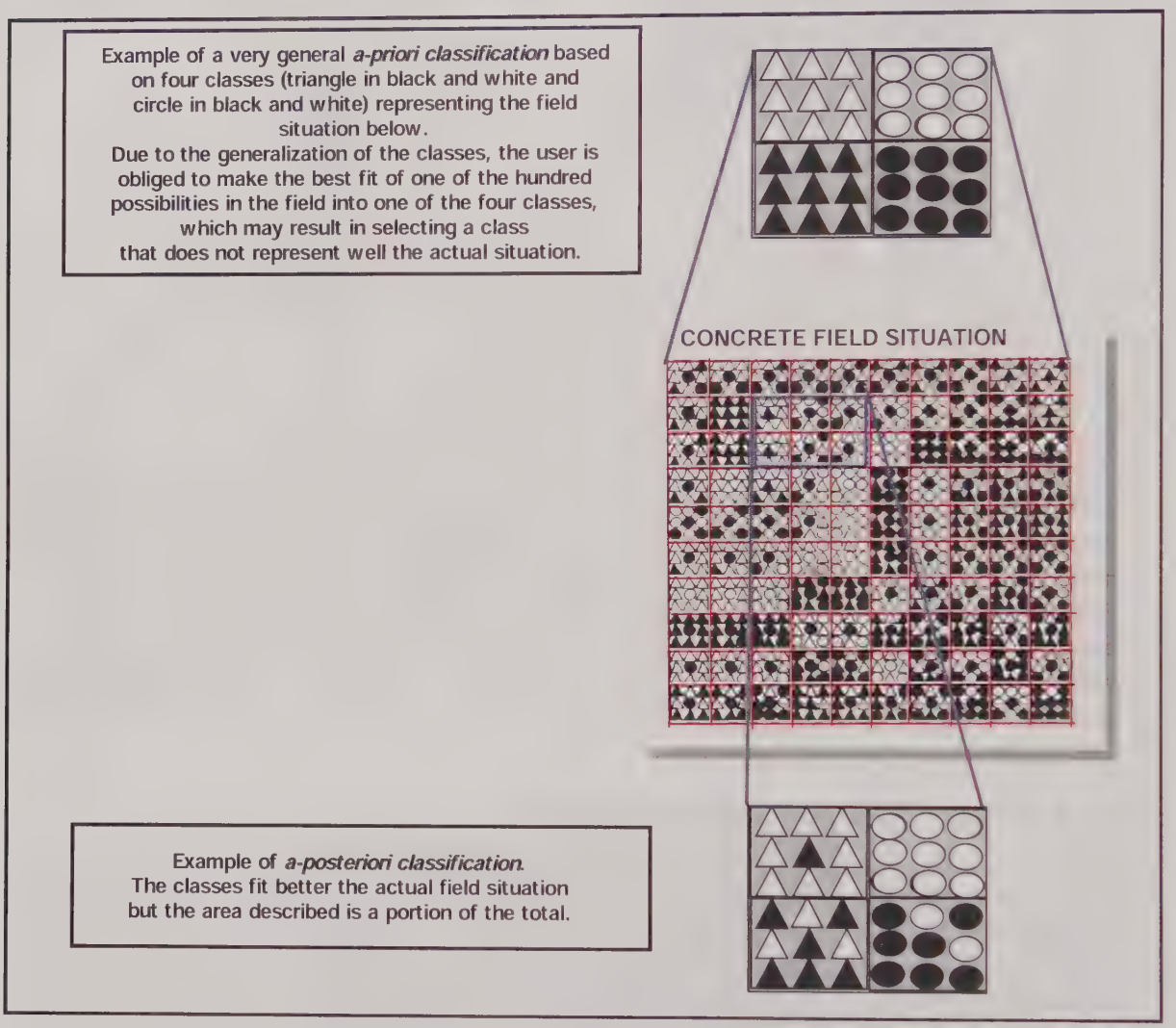
1.4 *A PRIORI* AND *A POSTERIORI* SYSTEMS

Classification can be done in two ways, that is either *a priori* or *a posteriori* (Figure 4). In an *a priori* classification system the classes are abstractions of the types actually occurring. The approach is based upon definition of classes before any data collection actually takes place. This means that all possible combinations of diagnostic criteria must be dealt with beforehand in the classification. This method is used extensively in plant taxonomy and soil science (e.g., The Revised Legend of the Soil Map of the World (FAO, 1988) and the USDA Soil Taxonomy (United States Soil Conservation Service, 1975)). The main advantage is that classes are standardized independent of the area and the means used. The disadvantage, however, is that this method is rigid, as some of the field samples may not be easily assignable to one of the pre-defined classes.

A posteriori classification differs fundamentally by its direct approach and its freedom from preconceived notions. The approach is based upon definition of classes after clustering similarity or dissimilarity of the field samples collected. The Braun-Blanquet method, used in vegetation science (this is a floristic classification approach using the total species combination to cluster samples in sociological groups (Kuechler and Zonneveld, 1988)), is an example of such an approach. The advantage of this type of classification is its flexibility and adaptability compared to the implicit rigidity of the *a priori* classification. The *a posteriori* approach implies a minimum of generalization. This type of classification better

fits the collected field observations in a specific area. At the same time, however, because an *a posteriori* classification depends on the specific area described and is adapted to local conditions, it is unable to define standardized classes. Clustering of samples to define the classes can only be done after data collection, and the relevance of certain criteria in a certain area may be limited when used elsewhere or in ecologically quite different regions.

FIGURE 4.
Example of an *a priori* (above) and *a posteriori* (below) classification related to a concrete situation in the field (adapted from Kuechler and Zonneveld, 1988).


Example of a very general *a-priori classification* based on four classes (triangle in black and white and circle in black and white) representing the field situation below.
Due to the generalization of the classes, the user is obliged to make the best fit of one of the hundred possibilities in the field into one of the four classes, which may result in selecting a class that does not represent well the actual situation.
CONCRETE FIELD SITUATION
Example of *a-posteriori classification*.
The classes fit better the actual field situation but the area described is a portion of the total.

2. THE CONCEPTUAL BASIS

2.1 PROBLEMS WITH CURRENT CLASSIFICATION SYSTEMS

Despite the necessity for a standard classification system, none of the current classifications has been internationally accepted (Danserau, 1961; Fosberg, 1961; Eiten, 1968; UNESCO, 1973; Mueller-Dombois and Ellenberg, 1974; Kuechler and Zonneveld, 1988; CEC, 1993; Duhamel, 1995). Often, the land cover classes are inappropriate for particular purposes (e.g., statistical or rural development needs), the scale is related to a specific purpose and the information is mostly obsolete. Furthermore, factors are often used in the classification system which result in a undesirable mixture of potential and actual land cover (e.g., including climate as a parameter). The reasons why none of the current classifications could serve as a reference system are manifold, as will be explained below.

2.1.1 Purpose

A proportion of the existing classifications are either vegetation classifications (e.g., Danserau, 1961; Fosberg, 1961; Eiten, 1968; UNESCO 1973; Mueller-Dombois and Ellenberg, 1974; Anderson *et al.*, 1976; Kuechler and Zonneveld, 1988), broad land cover classifications, or systems related to the description of a specific feature (e.g., agricultural areas). Thus, they are limited in their capacity to define the whole range of possible land cover classes. An illustration is the UNESCO Vegetation Classification (designed to serve primarily for vegetation maps at a scale of 1:1 000 000), which considers only natural vegetation, while all other vegetated areas, such as cultivated areas and urban vegetated areas, are ignored. Other vegetation classifications, even if they consider agricultural areas, do not describe these classes with the same level of detail as used for the natural vegetation ones. In contrast, systems used to describe agricultural areas give very few details in their description of natural vegetation.

Many systems have been developed for a certain purpose, at a certain scale, and using a certain data type (e.g., the IGBP-DISCover global 1 km data set based on the National Oceanic and Atmospheric Administration – Advanced Very High Resolution Radiometer (NOAA-AVHRR)). Hence the derived classes are strictly dependent on the means used (e.g., in the previous example the classes will be only those that can be detected using NOAA).

Many current classification systems are not suitable for mapping, and subsequent monitoring purposes. The use of the type of diagnostic criteria and their hierarchical arrangement to form a class is very often in conflict with the ability to define a clear boundary between two classes. For monitoring, land cover changes take two forms: conversion from one category to another (e.g., from forest to grassland), and modification of condition within one category (e.g., from natural vegetation to cultivated). The broader and fewer the categories used to describe land cover, the fewer the instances of conversion from one to another. If land cover classes are as broad as "forest and woodland", "arable land" and "permanent meadows and pastures" (from the FAO Production Yearbook) then forest fragmentation, a shift from rainfed to irrigated cultivated areas and less dense grass cover due to overgrazing will not register as conversion nor as modification. A multi-user-oriented classification system should capture both.

2.1.2 Consistency

In most current classifications, the criteria used to derive classes are not systematically applied. Often, the use of different ranges of values depends on the importance given by the user to a particular feature (e.g., in many systems the cover ranges to distinguish tree-dominated areas are many, whereas only one single cover range is used to define shrub- or grass- dominated areas).

In some classifications the class definition is imprecise, ambiguous or absent. This means that these systems fail to provide internal consistency (e.g., the frequency with which classes in the CORINE (Co-ordination of Information on the Environment) Land Cover system overlap with other classes elsewhere in the same classification (CEC, 1993)).

In most systems, the full combination of diagnostic elements describing a class is not considered (e.g., a system which describes vegetation with the diagnostic criteria of three ranges of cover matched with three ranges of height must consistently apply these ranges for all life forms considered). The reason why most systems fail in application of this basic classification rule is that the entire set of permutations of the possible classifiers would lead to a vast number of classes which cannot be handled with the current methods of class description (e.g., in the example above, if there were 10 classes of each, the result would be 100 combinations). Therefore, the current systems often leave gaps in the systematic application of the used diagnostic criteria.

Very often the systems contain a number of classes, which due to their interrelation and hierarchical structure, appear to be a proportion of a broader set of classes. Thus, these types of systems are mere legends. The characteristic of legends is that only a proportion or subset of the entire range of possible classes is described. Such legends have the disadvantage that the user cannot refer back to a classification system, which precludes comparisons with other systems.

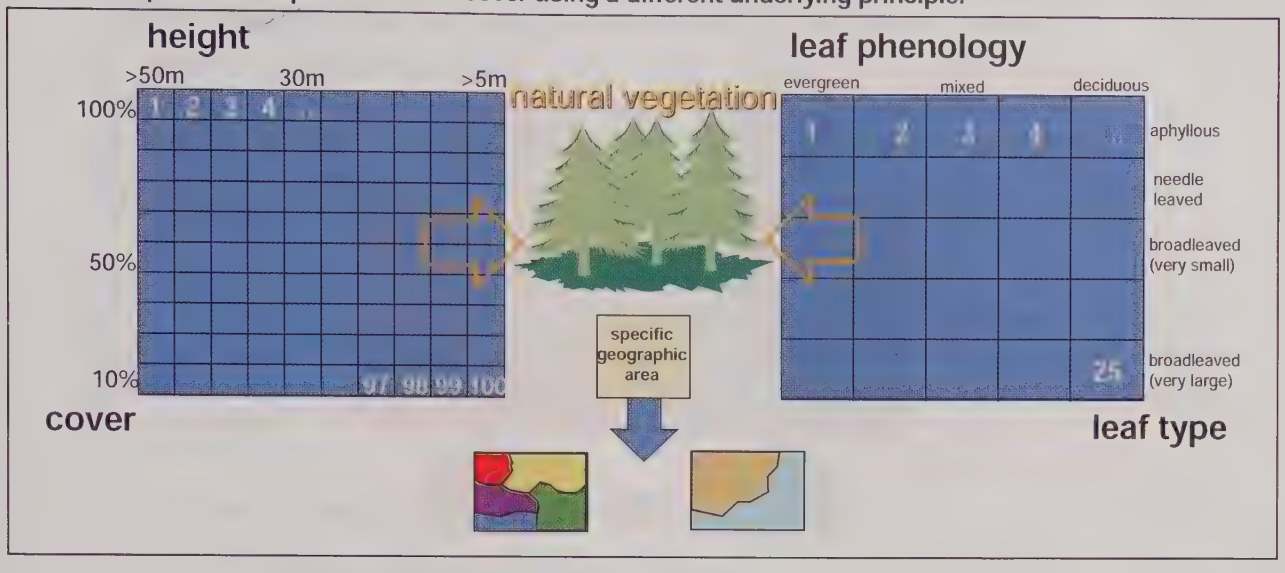
Threshold values are very often derived from knowledge of a specific geographic area, so that elsewhere the class boundary definition between two classes may become unclear, that is with overlaps or gaps. In these cases any comparisons will be impossible or inaccurate.

2.1.3 The Underlying Common Principle

An underlying common principle has often not been defined in land cover classification. A mixture of different features is used to define a class, especially features such as climate, geology, soil type and landform (thus, in "tropical rain forest" the term "tropical", which is usually climate related, is used to describe a certain floristic composition). Features such as climate, geology and landform influence land cover but are not *inherent features* of it. This type of combination is frequently found and is often applied in an irregular way without any hierarchy. This may lead to confusion in the definition of the class.

Classification of vegetation using the diagnostic criteria of "height" and "cover" will lead to a different perspective of the same feature in comparison with the use of "leaf phenology" and "leaf type" (Figure 5). It is therefore important to come to a basic understanding of the criteria to be used as underlying principles for land cover description.

FIGURE 5.
Example of description of a land cover using a different underlying principle.

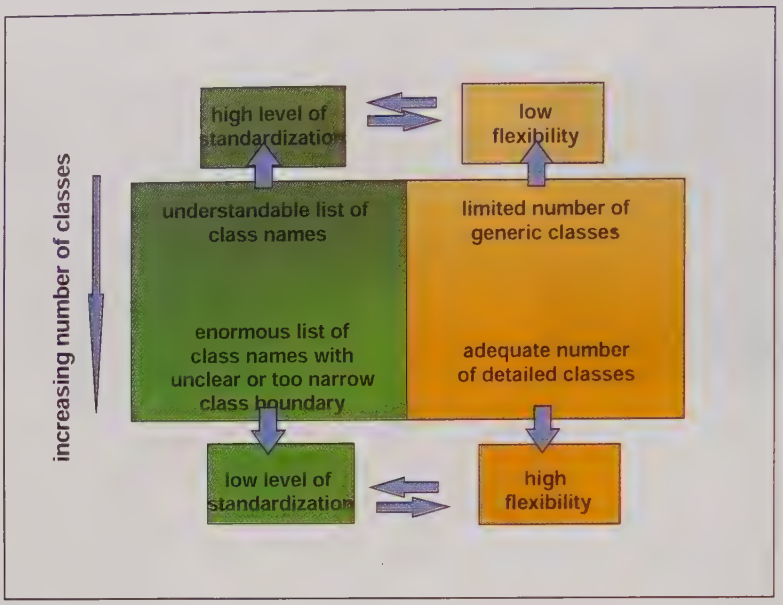


2.1.4 *A priori* classification systems

Often an *a priori* classification system is used in which classes are arranged. However, the use of such a classification assumes that all possible classes any user may derive, independent of scale and tools used, are included in the system. Having all classes pre-defined in the system is the intrinsic rigidity of an *a priori* classification system. The advantage of such a system is mainly that it is the most effective way to produce standardization of classification results between user communities. The disadvantage is that to be able to describe consistently any land cover occurring anywhere in the world, one needs an enormous amount of pre-defined classes. Such a system should be flexible in the sense that any occurring land cover can be accommodated. How can one introduce this type of flexibility while using the "classical" approach of class names and descriptions?

By increasing the number of classes in an *a priori* system, the problem arises of how the users will find their way through a "jungle" of class names (Figure 6). Furthermore, this situation aggravates standardization, namely that every user may have a slightly different opinion on how to interpret some classes because the class boundary definitions between classes will be based on very slight differences. The wrong, or different, designation of the same land cover feature in different classes will affect this standardization process that is one of the chief objectives of the classification system. Ultimately, the attempt to harmonize will fail. The *a priori* classification approach appears to be a vicious circle: the attempt to create this type of classification as a tool for standardization obliges one to fit the enormous variety of occurring land cover in a limited number of more generic classes, while the endeavour to create more classes increases the danger of having a lack of standardization, the very basic principle used as starting point.

FIGURE 6.
Problem of the current *a priori* classifications in relation to their flexibility.


high level of standardization
low flexibility
increasing number of classes
understandable list of class names
limited number of generic classes
enormous list of class names with unclear or too narrow class boundary
adequate number of detailed classes
low level of standardization
high flexibility

The above illustrates that there is not as much compatibility between classification systems, or between classification and legend, as may be desired. There are numerous inconsistencies in definition of classes, class boundaries, in the use of threshold values, etc. However useful the current classifications may be, these factors limit the possibility of the use of such classification results by a large audience for a broad range of applications.

In the context of developing a new system, it is fundamental to identify the criteria to which any reference classification, to the extent possible, should adhere (Box 1).

Box 1. General criteria for a reference classification.

The reference classification should be:

- *comprehensive, scientifically sound* and *practically oriented*;
- *meet the needs of a variety of users* (neither single-project oriented nor taking a sectoral approach); users can use just a sub-set of the classification and develop from there according to their own specific needs;
- potentially *applicable as a common reference system*, and facilitate comparisons between classes derived from different classifications;
- be a *flexible* system, which can be used at different scales and at different levels of detail allowing cross-reference of local and regional with continental and global maps without loss of information;
- *able to describe the complete range of land cover features* (e.g., forest and cultivated areas as well as ice and bare land, etc.), with clear class boundary definition that are unambiguous and unique;
- adapted to fully describe the whole variety of land cover types with the *minimal set of classifiers* necessary (the less classifiers used in the definition, the less the error expected and the less time and resources necessary for field validation); and
- based on a *clear and systematic description of the class*, where the diagnostic criteria used to define a class must be clearly defined, with pure land cover criteria distinct from environmental criteria (e.g., climate, floristic and altitude), as the latter influence land cover but are not inherent features.

2.2 THE BASIS FOR A NEW APPROACH

2.2.1 Adopted Definition of Land Cover

The common integrated approach adopted here defines land cover as *the observed (bio)physical cover on the earth's surface* (see Section 1.1, above), but, in addition, it is emphasized that land cover must be considered a geographically explicit feature which other disciplines may use as a geographical reference (e.g., for land use, climatic and ecological studies).

Land is a basic source of mass and energy throughput in all terrestrial ecosystems, and land cover and land use represent the integrating elements of the resource base. Land cover, being the expression of human activities, changes with modifications in these activities. Therefore, land cover as a geographically explicit feature can form a reference basis for other disciplines.

2.2.2 A New Approach to Classification

Increasing flexibility while maintaining mapability

To create a standardized, hierarchical, consistent, *a priori* classification system containing systematic and strict class boundary definitions implies the basic requirement of having to build flexibility into the classification system. In this context, flexibility has different meanings. First of all, flexibility should address the potential for the classification system to describe enough classes to cope with the real world. At the same time, however, flexibility should adhere to strict class boundary definitions that should be unambiguous and clear. In addition, the classes in such a system should be as neutral as possible in the description of a land cover feature in order to answer to the needs of a wide variety of end-users and disciplines.

Many current classification systems are not generally suitable for mapping, and subsequent monitoring, purposes. The integrated approach requires clear distinction of class boundaries. Furthermore, the use of diagnostic criteria and their hierarchical arrangement to form a class should be a function of the *mapability*, that is the ability to define a clear boundary between two classes. Hence, diagnostic criteria should be hierarchically arranged in order to assure at the highest levels of the classification a high degree of geographical accuracy.

How does one increase the classification system's flexibility while maintaining the principle of mapability and aiming at standardization? These prerequisites can only be accomplished if the classification has the possibility of generating a high number of classes with clear boundary definitions. In other words, it should be possible to delineate a large number of classes in order to suit the enormous variation of land cover features, while maintaining the clear distinction of class boundaries. In current classification systems this possibility is hampered by the manner in which these classifications are set up. Differences between classes can only be derived from class descriptions. Therefore, it would be very difficult for the user to distinguish between such classes just based upon class names or unsystematic descriptions, as is the case with most of the current classification systems.

Basic principle

One of the basic principles adopted in the new approach is that a given land cover class is defined by the combination of a set of independent diagnostic attributes, the so-called *classifiers*. The increase of detail in the description of a land cover feature is linked to the increase in the number of classifiers used. In other words, the more classifiers added, the

more detailed the class. The class boundary is then defined either by the different amount of classifiers, or by the presence of one or more different types of classifiers. Thus, emphasis is no longer on the class name, but on the set of classifiers used to define this class.

Issues impeding application of the new approach

The straightforward application of this condition is hampered by two main factors. First, land cover should describe the whole observable (bio)physical environment and therefore deals with a heterogeneous set of classes. Obviously, a forest is best defined using a set of classifiers which differ from those to describe snow-covered areas. Instead of using the same set of classifiers to describe such heterogeneous features, in the new approach the classifiers are tailored to major land cover features. According to the general concept of an *a priori* classification, it is fundamental to the system that all the combinations of the classifiers must be created in the system. By tailoring the set of classifiers to the major land cover features, all combinations can be made without having a tremendous number of theoretical but redundant combinations of classifiers. Secondly, two distinct land cover features, having the same set of classifiers to describe them, may differ in the hierarchical arrangement of these classifiers in order to ensure a high mapability.

2.3 LAND COVER CLASSIFICATION SYSTEM: DESIGN CRITERIA

Land cover classes are defined by a string of classifiers, but due to the heterogeneity of land cover, and with the aim of achieving a logical and functional hierarchical arrangement of the classifiers, certain design criteria have been applied.

The Land Cover Classification System (LCCS) has been designed with two main phases (Figure 7):

An initial *Dichotomous Phase*, in which eight major land cover types are defined:

- Cultivated and Managed Terrestrial Areas
- Natural and Semi-Natural Terrestrial Vegetation
- Cultivated Aquatic or Regularly Flooded Areas
- Natural and Semi-Natural Aquatic or Regularly Flooded Vegetation
- Artificial Surfaces and Associated Areas
- Bare Areas
- Artificial Waterbodies, Snow and Ice, and
- Natural Waterbodies, Snow and Ice.

This is followed by a subsequent so-called *Modular-Hierarchical Phase*, in which land cover classes are created by the combination of sets of pre-defined classifiers. These classifiers are tailored to each of the eight major land cover types.

The tailoring of classifiers in the second Phase allows the use of most appropriate classifiers to define land cover classes derived from the major land cover types and at the same time reduces the likelihood of impractical combinations of classifiers. This results in a land cover class defined by:

- a *Boolean formula* showing each classifier used (all classifiers are coded);

- a *unique number* for use in Geographical Information Systems (GIS); and
- a *name*, which can be the standard name as supplied or a user-defined name.

TABLE 1.
Distinction at the main Dichotomous level and the second level.

Classifiers used	Land Cover Class Name and Description
DICHOTOMOUS PHASE: INITIAL-LEVEL DISTINCTION	
Presence/Absence of Vegetation: *Primarily vegetated*	A. Primarily Vegetated Areas: This class applies to areas that have a vegetative cover of at least 4% for at least two months of the year. This cover may consist of the life forms *Woody* (Trees, Shrubs), *Herbaceous* (Forbs, Graminoids) or a combination of them, or consist of Lichens/Mosses (only when other life forms are absent). A separate cover condition exists for Lichens/Mosses that can be only applied if this life form contributes at least 25% to the total vegetative cover (see Appendix A).
Presence/Absence of Vegetation: *Primarily non-vegetated*	B. Primarily Non-Vegetated Areas: This class includes areas that have a total vegetative cover of less than 4% for more than 10 months of the year, or in the absence of Woody or Herbaceous life forms less than 25% cover of Lichens/Mosses
DICHOTOMOUS PHASE: SECOND-LEVEL DISTINCTION	
Primarily vegetated Edaphic Condition: *Terrestrial*	A1. Terrestrial Primarily Vegetated Areas: The vegetation is influenced by the edaphic substratum.
Primarily non-vegetated Edaphic Condition: *Terrestrial*	B1. Terrestrial Primarily Non-Vegetated Areas: The cover is influenced by the edaphic substratum.
Primarily vegetated Edaphic Condition: *Aquatic or regularly flooded*	A2. Aquatic or Regularly Flooded Primarily Vegetated Areas: The environment is significantly influenced by the presence of water over extensive periods of time. The water is the dominant factor determining natural soil development and the type of plant communities living on its surface. Includes marshes, swamps, bogs and all areas where water is present for a substantial period regularly every year. This class includes floating vegetation.
Primarily non-vegetated Edaphic Condition: *Aquatic or regularly flooded*	B2. Aquatic or Regularly Flooded Primarily Non-Vegetated Areas: The environment is significantly influenced by the presence of water over an extensive period of time each year.

TABLE 2.
Distinction at the third level of the Dichotomous Phase into eight major land cover categories.

DICHOTOMOUS PHASE: TERTIARY-LEVEL DISTINCTION	
Primarily vegetated Terrestrial Artificiality of Cover: *Artificial/managed*	A11. Cultivated and Managed Terrestrial Areas: This class refers to areas where the natural vegetation has been removed or modified and replaced by other types of vegetative cover of anthropogenic origin. This vegetation is artificial and requires human activities to maintain it in the long term. In between the human activities, or before starting crop cultivation, the surface can be temporarily without vegetative cover. Its seasonal phenological appearance can be regularly modified by humans (e.g., tillage, harvest, and irrigation). All vegetation that is planted or cultivated with an intent to harvest is included in this class (e.g., wheat fields, orchards, rubber and teak plantations).
Primarily vegetated Terrestrial Artificiality of Cover: *(Semi-)natural*	A12. Natural and Semi-Natural Vegetation: Natural vegetated areas are defined as areas where the vegetative cover is in balance with the abiotic and biotic forces of its biotope. Semi-natural vegetation is defined as vegetation not planted by humans but influenced by human actions. These may result from grazing, possibly overgrazing the natural phytocenoses, or else from practices such as selective logging in a natural forest whereby the floristic composition has been changed. Previously cultivated areas which have been abandoned and where vegetation is regenerating are also included. The secondary vegetation developing during the fallow period of shifting cultivation is a further example. The human disturbance may be deliberate or inadvertent. Hence semi-natural vegetation includes vegetation due to human influences but which has recovered to such an extent that species composition and environmental and ecological processes are indistinguishable from, or in a process of achieving, its undisturbed state. The vegetative cover is not artificial, in contrast to classes A11 and A24, and it does not require human activities to be maintained in the long term.
Primarily vegetated Aquatic or Regularly Flooded Artificiality of Cover: *Artificial/managed*	A23 Cultivated Aquatic or Regularly Flooded Areas: This class includes areas where an aquatic crop is purposely planted, cultivated and harvested, and which is standing in water over extensive periods during its cultivation period (e.g., paddy rice, tidal rice and deepwater rice). In general, it is the emerging part of the plant that is fully or partly harvested. Other plants (e.g., for purification of water) are free-floating. They are not harvested but they are maintained. This class excludes irrigated cultivated areas.
Primarily vegetated Aquatic or Regularly Flooded Artificiality of Cover: *(Semi-)natural*	A24. Natural and Semi-Natural Aquatic or Regularly Flooded Vegetation: This class describes areas which are transitional between pure terrestrial and aquatic systems and where the water table is usually at or near the surface, or the land is covered by shallow water. The predominant vegetation, at least periodically, comprises hydrophytes. Marshes, swamps, bogs or flats where drastic fluctuations in water level or high concentration of salts may prevent the growth of hydrophytes are all part of this class. The vegetative cover is significantly influenced by water and dependent on flooding (e.g., mangroves, marshes, swamps and aquatic beds). Occasionally-flooded vegetation within a terrestrial environment is not included in this class. *Natural Vegetated Aquatic* habitats are defined as biotopes where the vegetative cover is in balance with the influence of biotic and abiotic forces. *Semi-Natural Aquatic* vegetation is defined as vegetation that is not planted by humans but which is influenced directly by human activities that are undertaken for other, unrelated purposes. Human activities (e.g., urbanization, mining and agriculture) may influence abiotic factors (e.g., water quality), affecting species composition. Furthermore, this class includes vegetation that developed due to human activities but which has recovered to such an extent that it is indistinguishable from its former state, or which has built up a new biotope which is in balance with the present environmental conditions. A distinction between Natural and Semi-Natural Aquatic Vegetation is not always possible because human activities distant to the habitat may create chain reactions which ultimately disturb the aquatic vegetative cover. Human activities may also take place deliberately to compensate for effects as noted above with the aim of keeping a "natural" state.

Classifiers used	Land Cover Class Name and Description
Primarily non-vegetated Terrestrial Artificiality of Cover: *Artificial/managed*	B15. Artificial Surfaces and Associated Areas: This class describes areas that have an artificial cover as a result of human activities such as construction (cities, towns, transportation), extraction (open mines and quarries) or waste disposal.
Primarily non-vegetated Terrestrial Artificiality of Cover: *(Semi-)natural*	B16. Bare Areas: This class describes areas that do not have an artificial cover as a result of human activities. These areas include areas with less than 4% vegetative cover. Included are bare rock areas, sands and deserts.
Primarily non-vegetated Aquatic or Regularly Flooded Artificiality of Cover: *Artificial/managed*	B27. Artificial Waterbodies, Snow and Ice: This class applies to areas that are covered by water due to the construction of artefacts such as reservoirs, canals, artificial lakes, etc. Without these the area would not be covered by water, snow or ice.
Primarily non-vegetated Aquatic or Regularly Flooded Artificiality of Cover: *(Semi-)natural*	B28. Natural Waterbodies, Snow and Ice: This class refers to areas that are naturally covered by water, such as lakes, rivers, snow or ice. In the case of rivers, the lack of vegetation cover is often due to high flow rates and/or steep banks. In the case of lakes, their geological origin affects the life conditions for aquatic vegetation. The following circumstances might cause water surfaces to be without vegetation cover: depth, rocky basins, rocky and/or steep shorelines, infertile washed-in material, hard and coarse substrates.

2.3.1 Dichotomous Phase

As stated above, a dichotomous key is used at the main level of classification to define the major land cover classes (Figure 7). Each major land cover type is defined as shown in Tables 1 and 2.

Three classifiers are used in the Dichotomous Phase, namely *Presence of Vegetation*, *Edaphic Condition* and *Artificiality of Cover*. These three classifiers have been hierarchically arranged, although independent of this arrangement the same eight major land cover types would be keyed out. The hierarchical arrangement is thus not important in this Phase, but is a guiding principle in the subsequent Modular-Hierarchical Phase.

2.3.2 Modular-Hierarchical Phase

In this phase the creation of the land cover class is given by the combination of a set of pre-defined pure land cover classifiers. This set of classifiers is different for each of the eight main land cover types (Appendix B and C). This difference is due to the tailoring of the classifiers to their respective type (see Figure 8).

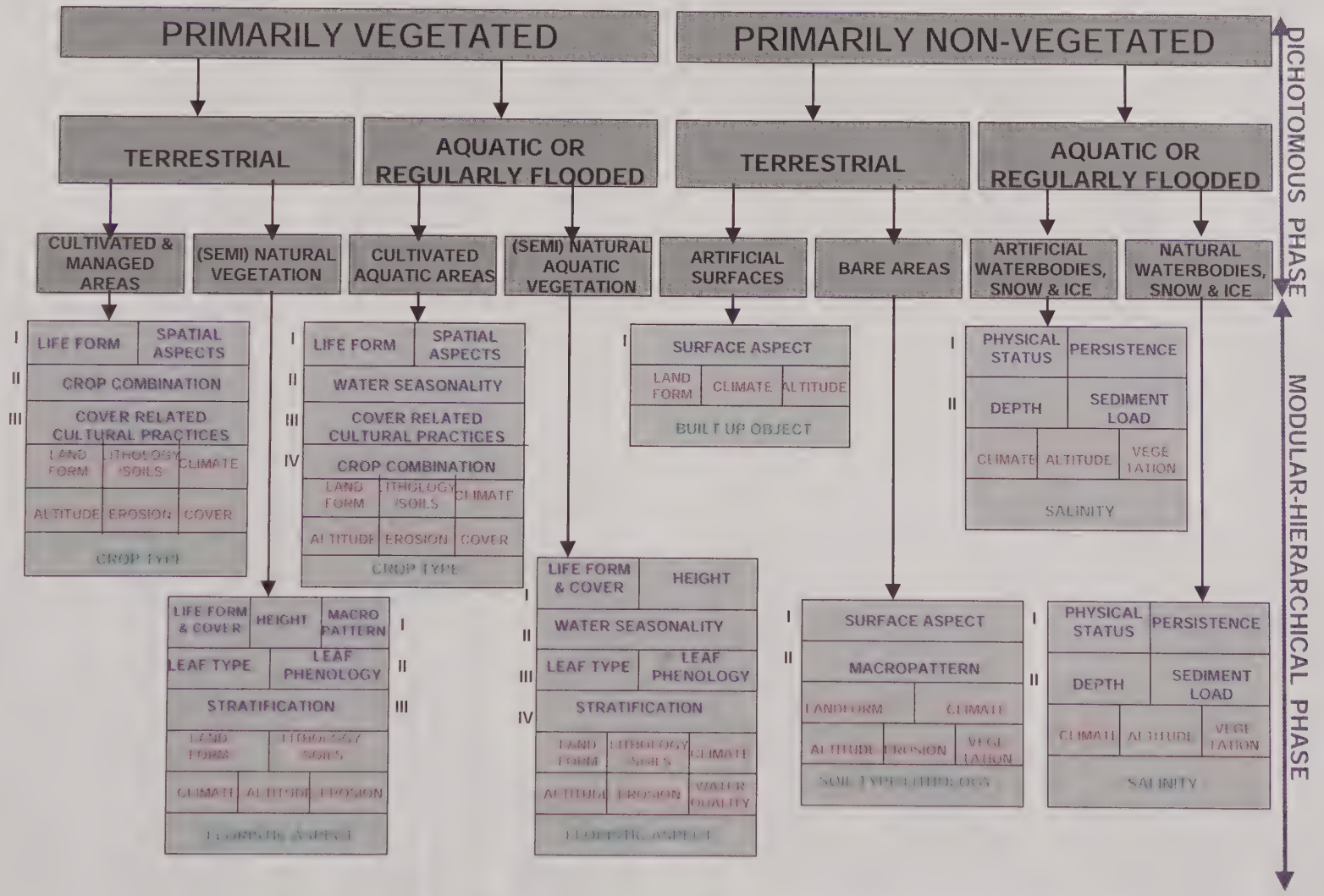


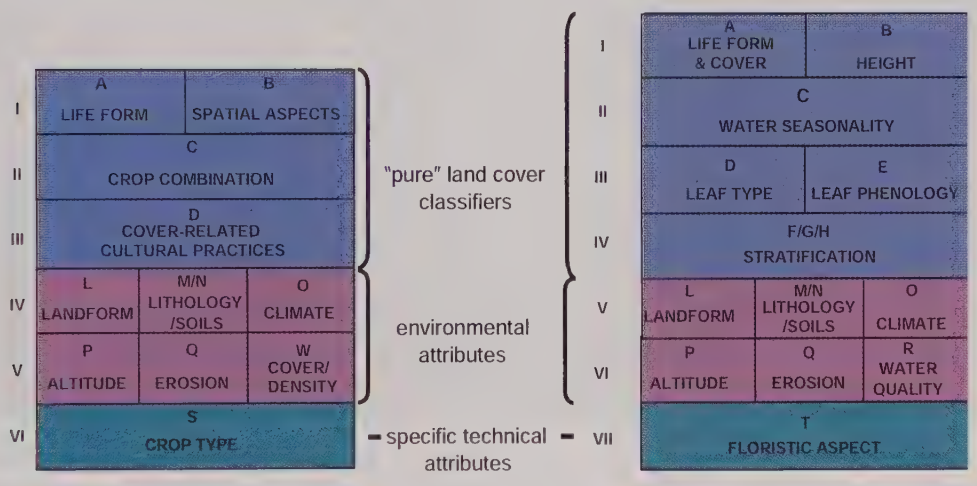
FIGURE 7. **Overview of the Land Cover Classification System, its two phases and the classifiers.**

These pure land cover classifiers can be combined with so-called *attributes* for further definition. Two types of attributes, which form separate levels in the classification, are distinguished (Figure 8 for two examples):

- *Environmental Attributes*: these attributes (e.g., climate, landform, altitude, soils, lithology and erosion) influence land cover but are not inherent features of it and should not be confused with "pure" land cover classifiers. These attributes can be combined in any user-defined order; and

- *Specific Technical Attributes*: these attributes refer to the technical discipline. For (Semi-)Natural Vegetation, the *Floristic Aspect* can be added (the method how this information was collected as well as a list of species); for Cultivated Areas, the *Crop Type* can be added either according to broad categories commonly used in statistics or by crop species; and for Bare Soil, the *Soil Type* according to the FAO/UNESCO Revised Soil Legend can be added). These attributes can be added freely to the pure land cover class without any conditions.

FIGURE 8.
The Modular-Hierarchical Phase: example of tailoring of the classifiers and attributes for the "Cultivated and Managed Terrestrial Areas" (left) and "Natural and Semi-Natural Aquatic or Regularly Flooded Vegetation" (to the right).



The user is obliged to start with the pure land cover classifiers. However, at any time the user can stop – dependent upon the level of detail required – and derive a land cover class (Table 3). Further definition of this class can be achieved by adding a single or a combination of any of the other types of attributes. These attributes are not hierarchically ordered and selection of them will generate a separate coded string.

Because the classification is suitable for mapping purposes, the system gives high priority to "mapability." and therefore the user needs to follow specific rules:

- A higher level of land cover classifier must be used before going to a lower level (because mapability is high at higher levels and decreases with lower levels).

- Within certain levels of land cover classifier there are pure land cover classifiers, and a further subdivision of them, the *modifiers*, which refine the classifier further but are optional and do not necessarily need to be determined.

- All land cover classifiers at one level of the classification have to determined before the system allows one to go to the next level.
- At any time inside a land cover classifier level the user can stop, and a mutually exclusive class is defined.
- All land cover classes defined in such way are hierarchically arranged in the Legend (see Legend Module).
- At any time the user can further define the land cover class using environmental or specific technical attributes, alone or in combination. These attributes will add a second, separate, code to the land cover class because they are not inherent features of land cover.
- A Boolean formula (i.e., a combination of the classifiers used), a unique code (numerical) and a name (nomenclature) define each land cover class.

TABLE 3.
Example of the formation of land cover classes.

Example "Natural and Semi-Natural Terrestrial Vegetation (A12)":

Classifiers Used:	Boolean Formula:	Standard Class Name:	Code:
Life Form & Cover	A3A10	Closed Forest	20005
Height	A3A10B2	High Closed Forest	20006
Spatial Distribution	A3A10B2C1	Continuous Closed Forest	20007
Leaf Type	A3A10B2C1D1	Broadleaved Closed Forest	20095
Leaf Phenology	A3A10B2C1D1E2	Broadleaved Deciduous Forest	20097
2nd Layer: LF, C, H	A3A10B2C1D1E2F2F5F7G2	Multi-Layered Broadleaved Deciduous Forest	20628
3rd Layer: LF, C, H	A3A10B2C1D1E2F2F5F7G2 F2F5F10G2	Multi-Layered Broadleaved Deciduous Forest With Emergents	20630

2.3.3. Concepts for the Primarily Vegetated Areas

There are different ways of making an orderly arrangement of the *Primarily Vegetated Areas*, with varying success according to region or purpose. Vegetation has a multitude of properties and features, and a certain degree of abstraction is required when classifying. However, agreement could be reached on selection of a relatively small number of diagnostic criteria to identify plant communities.

Plant communities, or phytocenoses, are characterized by two important features:

- all plant communities consist of *growth forms*; and
- all plant communities consist of *plant species*.

This applies to all phytocenoses on earth (Kuechler and Zonneveld, 1988). Growth forms (e.g., trees, shrubs, herbaceous, etc.) are so important that various vegetation scientists have used them as criteria for classification (Danserau, 1961; Mueller-Dombois and Ellenberg, 1974). The growth forms are distributed within the plant community in layers or *strata*. This stratification is common and the distinction of the individual strata is of fundamental importance when analysing the plant community. Plant communities are not limited to vertical arrangement into layers: they are also arranged horizontally (i.e., the horizontal spatial distribution).

Thus, when observing plant communities and considering their growth forms, two factors are fundamental:

- *physiognomy*, the overall appearance of the vegetation; and
- *vegetation structure* which is defined as "the spatial distribution pattern of growth forms in a plant community" (Kuechler and Zonneveld, 1988). The structure, then, describes the individual strata, usually characterized by height and density or coverage of the respective growth forms.

At the same time, a plant community consists of *taxa* (botanical species) that are usually unevenly distributed insofar as some may be common, or dominant, while others are less conspicuous. The component taxa can be used to describe the plant community as well as the structure. A description using taxa is called the *floristic composition* of the plant community. The floristic composition usually contains all species, though it is unusual to include the rare or incidental ones.

The various existing classification systems have emphasized one or other of the above (e.g., physiognomic-structural systems; floristic systems; physiognomic-floristic systems). There is no doubt that a full description of a plant community must consider both physiognomic-structural and floristic aspects. A phytocenose can have the same structural aspect but different floristic composition, as well as the same floristic composition but a different structural aspect. However, problems arise when attempting to incorporate both types of information in a single classification system.

In the Land Cover Classification System, *Natural and Semi-Natural Vegetation*, in both the *Terrestrial Areas* (A12) and *Aquatic or Regularly Flooded Areas* (A24), are classified using a pure physiognomic-structural method. The aspects considered are, thus: (1) physiognomy; (2) vertical and horizontal arrangement; (3) leaf type; and (4) leaf phenology of plants. This concept has been adopted with the conviction that only a pure structural representation of vegetation is able to incorporate, without any confusion of

terms, floristic aspects of vegetation as well as environmental attributes (e.g., landform, climate, altitude, etc.). The proposed classification allows the user to add freely these attributes at any level of the created structural land cover class (Appendix B and C).

Users not familiar with classical vegetation classification and mapping (Eiten, 1968; UNESCO, 1973; White, 1983; Kuechler and Zonneveld, 1988) or ecological studies should be able to build up a scientifically sound vegetation classification by following the Land Cover Classification System. This will avoid the separation between classical vegetation classification and land cover classification. A variety of users should be able to apply the results of the classification, even those who are not specialized in vegetation mapping.

The physiognomic-structural approach selected for classification of vegetated areas in a land cover classification system poses a challenge with regard to classification of vegetated areas other than (semi-)natural vegetated areas, namely cultivated and urban vegetated areas. These managed vegetated areas are also characterized by plant communities having growth forms and taxa, a structure and a floristic composition. Therefore, the physiognomic-structural approach adopted is equally applicable to such areas. Using the same approach to describe and classify this type of area at a certain level of detail has the advantage that all *Primarily Vegetated Areas* can be compared.

2.3.3.1 Natural and Semi-Natural Vegetation (A12 and A24)

General rules for classification

Before starting to use the classifiers, the user has to take into account some basic rules governing the concepts of classification of *(Semi-)Natural Vegetation*, namely:

- the definition of *Life Form*; and
- the definition of *dominance*

These two main aspects are very important and must be carefully determined because in the software the determination of Main *Life Form* has consequences for the selections available at subsequent levels. Certain choices at a high level of the system may disable choices at lower levels.

- *Life Form* of a plant is defined by its physiognomic aspect. This is the case when *Woody* plants, subdivided into *Trees* and *Shrubs*, are distinguished from *Herbaceous* plants, subdivided into *Forbs* and *Graminoids*, and *Lichens/Mosses*.

- A condition of *Height* is applied to separate *Trees* from *Shrubs*: woody plants higher than 5 m are classified as *Trees*. In contrast, woody plants lower than 5 m are classified as *Shrubs*. This general rule is subject to the following exception: a woody plant with a clear physiognomic aspect of trees can be classified as *Trees* even if the *Height* is lower than 5 m but more than 3 m. In this case, a subcondition of physiognomic aspect is added to the *Height* condition.

These are the limits recommended for *Life Form* distinction, but exceptions are allowed:

- Plants essentially herbaceous but with a woody appearance (e.g., bamboos and ferns) are classified as *Trees* if the height is more than 5 m, and as *Shrubs* if the height is less than 5 m.

These are the recommended thresholds for *Life Form* characterization.

Concerning the concept of dominance, two criteria need to be considered:

- The main criteria is the **uppermost canopy layer**. This means that the dominant layer goes from *Tree* canopy to *Shrub* to *Herbaceous/Forbs/Graminoids.*

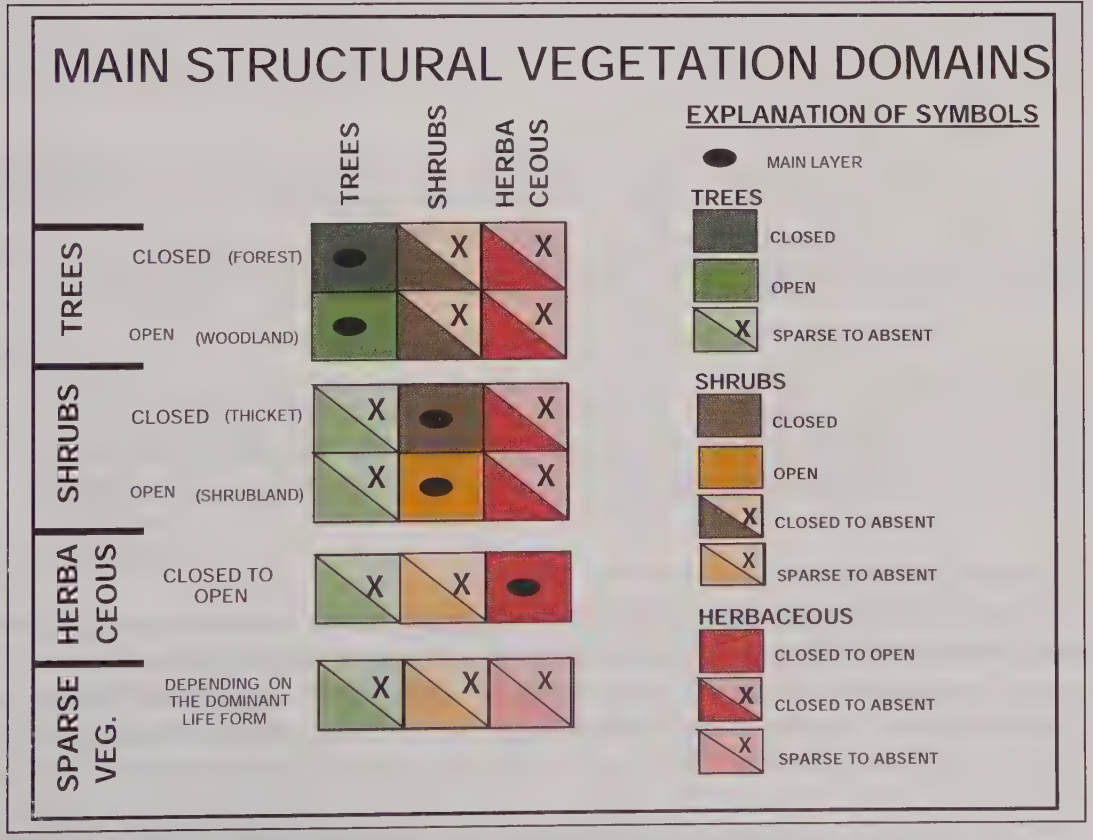
- This general rule is subject to a **sub-condition of *Cover***: it is only valid if the dominant *Life Form* has a Cover either *Closed* or *Open.* If the *Life Form* is *Sparse,* the dominance goes to another *Life Form* that has a *Closed* or *Open* cover (Figure 9).

When the user has decided these two main aspects, the building of classes can start. The rules explained above show that in order to determine a *(Semi-)Natural Vegetation* class, a minimum of three classifiers need to be selected:

- Life Form
- Cover
- Height

These are the minimum elements required to form a *Natural* or *Semi-Natural* Vegetated land cover class, for both *Terrestrial* and *Aquatic or Regularly Flooded Areas.* Because *Height* (in its standard denotation) is automatically linked to the *Life Form* chosen, the classifiers needing to be determined are actually two: *Life Form* and *Cover.*

FIGURE 9.
Main Structural Vegetation Domains (Di Gregorio and Jansen, 1996a).



A. Life Form and Cover

A *Life Form* is a group of plants having certain morphological features in common (Kuechler and Zonneveld, 1988). According to the quality of the main axis or shoots, a further distinction is made into *Woody* or *Herbaceous*. For further subdivision, the following growth form criteria can be applied:

- *Branching symmetry*, subdividing Trees and Shrubs; and
- *Herbaceous plant physiognomy*, subdividing *Forbs* from *Graminoids* (Strasburger *et al.*, 1983; Kuechler and Zonneveld, 1988) and from *Lichens/Mosses*.

The full definitions and guidelines for application in the system are found in the Help of the software application, and as Appendix A here.

Cover can be considered as the presence of a particular area of the ground, substrate or water surface covered by a layer of plants considered at the greatest horizontal perimeter level of each plant in the layer (according to Eiten, 1968). A distinction is made between Closed (>(60 – 70) percent), Open (between (60 – 70) and (10 – 20) percent) and Sparse (below (10 – 20) percent but >1 percent). As herbaceous plants are seasonal in character, it is always assessed in terms of fullest development.

The reason for expressing cover in terms of ranges instead of absolute values is discussed in the relevant guidelines of the software application and in Appendix A here.

B. Height

The *Height* of a certain layer is measured from the ground to the average top of the life form that is being examined (Kuechler and Zonneveld, 1988). The fact that single plants of one synusia differ from the average height can be ignored, apart from the fact that they can form their own layer (e.g., the emergents of a rainforest that tower above the rest). The *Height* is classed as: Trees >30 – 3 m; Shrubs 5 – 0.3 m; and Herbaceous 3 m – 0.03 m. Each class can be further subdivided.

The major *Height* classes are linked to the *Life Form* selected. These classes provide general information regarding height because, in the concept of the classification, this criterion has not been given a prevalent importance. The user can choose to remain at this generic level, or to go to the modifiers, whereupon the importance of height increases.

In the case of *Shrubs* or *Herbaceous* (Forbs or Graminoids) life forms, it is strongly recommended not to remain at the level of the standard definition of *Height*, if this is possible, but instead to select one of the modifiers. The ecological significance of these life forms can be strongly correlated with height (e.g., separation between low and tall herbs or between dwarf and high shrubs, especially concerning potential for grazing/rangeland).

C. Spatial Distribution or Macropattern

The next classifier that can be applied is the *Macropattern*. It is defined as the *horizontal spatial distribution of vegetation in a certain area*. It should not be confused with *Cover* because that defines the spatial arrangement of *Life Forms* (e.g., trees, shrubs, etc.). Macropattern describes the spatial arrangement of specific structural vegetation types (e.g., *Closed Forest, Closed Shrubs*). This classifier may seem unusual, but there are good reasons:

- Often the *Macropattern* reflects an ecological or an evolutionary aspect of vegetation (e.g., scattered vegetation in arid areas; agricultural encroachment inside forest areas;

degradation due to overgrazing; etc.). In many classifications, one find terms that are extremely subjective, like "Degraded Forest" or similar. The present classification aims to be neutral in its land cover description without including ambivalent terminology. Therefore *Macropattern* is used as a neutral classifier to describe vegetation status;

- this classification has been built up for mapping purposes, therefore spatial distribution of land cover is an important aspect; and

- macropattern is easy detectable from remote sensing data (photographs and imagery), i.e., it has good "mapability."

Macropattern should thus be used to give supplementary ecological information (or to show a human-induced degradational aspect of natural vegetation). The user has the possibility of skipping this classifier if it is felt to be irrelevant.

The combinations between *Cover* and *Macropattern* are unrestricted (this is nevertheless only valid for *Closed* and/or *Open Cover,* as will be explained later) which means that, for instance, a Closed Tree formation (Closed Forest) can be either *Continuous* or *Fragmented* depending on its spatial distribution in the mapping unit.

Because of this dimensional aspect, *Macropattern* is linked with the mapping scale. This may seem a contradiction with the main classification concept explained above, namely that the elements of a classification system must be scale-independent. To determine *Macropattern,* one should refer to the overall appearance of a vegetation formation in a certain area in a homogeneous landscape. However, if one wants to be more precise or objective in the application of this classifier, some specific rules are given below to help the user who is not familiar with this concept in order to standardize the interpretation. Because we are dealing with the practical application of this concept in a cartographic context, the concepts of mixed units and minimum mappable areas will be used. These concepts are further described in Section 2.5.

A certain structural vegetation type has a continuous *Macropattern* if, inside the minimum mappable area, it covers more than 80 percent of the area.

A particular structural vegetation type would be considered a *Fragmented Macropattern* if inside the minimum mappable area it covers more than 20 percent but less than 80 percent. This situation is linked with the concept of mixed unit. Three cases are possible:

- The structural vegetation type (e.g., dense forest) covers more than 50 percent of the area and the other element (e.g., agricultural fields) covers less than 50 percent but more than 20 percent. In this case the resulting unit will be a mixed unit with the fragmented dense forest as the dominant one (e.g., fragmented dense forest/agricultural fields).

- The structural vegetation type (e.g., dense forest) covers less than 50 percent but more than 20 percent of the area. The other element (e.g., agricultural fields) covers more than 50 percent. In this case the class is also mixed, but the dominant class will be the agricultural fields (i.e., agricultural fields/fragmented dense forest).

- When a unit contains three elements (e.g., fragmented dense forest, agricultural fields and bare areas) the rules for mixed units should be applied (see Section 2.5). In this case it could be possible to have a structural vegetation type with a *Fragmented*

Macropattern as single unit (e.g., fragmented dense forest, 70 percent; agricultural fields, 15 percent; and bare areas, 15 percent. As neither of the subsidiary elements reach a cover exceeding 20 percent, the unit must be considered a single mapping unit of fragmented dense forest). This is the only case when a structural vegetation type with *Fragmented Macropattern* must be considered as a single mapping unit. Even if theoretically possible, this case must be considered a very unusual one, and therefore should be avoided.

The *Continuous* or *Fragmented* classifiers are linked with the Cover, *Closed* or *Open* (e.g., Closed Continuous Forest, Closed Fragmented Forest, Continuous Woodland and Fragmented Woodland). Fragmentation can be further subdivided into *Striped* or *Cellular* (e.g., the tiger bush in the Sahel, where Closed Shrubs are present in the interdunal areas, which can be represented as Fragmented (Striped) Closed Shrubs).

The *Parklike Patches* Macropattern is directly linked with the cover category *Sparse*. Basically, this is simply redundant information. When the user defines the cover of a certain life form to be Sparse, the only Macropattern available for this structural vegetation type is Parklike Patches.

The Macropattern concept is preferentially used for Woody *Life Forms* (Trees, Shrubs). Herbaceous *Life Forms* (Graminoids, Forbs) can have a Macropattern, but this is subordinated to the absence of Woody *Life Forms*. When linear patches of dense shrubs (typical of tiger bush) are present together with dense herbaceous vegetation filling the space between patches, one could have two different perspectives of this situation, either *Fragmented Shrubs/Herbaceous* or *Fragmented Herbaceous/Shrubs*. In the application of the Macropattern, the rule obliges the user to always give preference, to the Woody component. Macropattern can be applied to Herbaceous *Life Forms* only when there is no significant presence of Woody *Life Forms* (Trees, Shrubs). For instance, patches of dense herbaceous vegetation in sandy areas can be called fragmented herbaceous/sand.

A structural vegetation type is *Fragmented* when the size of the patches of the vegetation are between 1/15 and 1/2 of the minimum mappable unit. This rule is a very artificial one and should not be rigidly applied. Nevertheless, the rule assists the user by providing some reference indicator of what a Fragmented Macropattern should look like. If the patches become too small, at a certain level they could coincide with the life form itself, thus contradicting the basic rule explained above, namely that Macropattern describes the specific arrangement of structural vegetation types and must not be confused with the cover of the life form.

If all the above mentioned classifiers are determined, the user can enter the next level and add a new set of information.

C. Water Seasonality

For Aquatic or Regularly Flooded Natural and Semi-Natural Vegetation (A24), the second level classifier consist of *Water Seasonality*. This classifier can be considered as the type of persistence of the water at or near the surface. There are three subdivisions:

- *(Semi-)Permanent* (more than four months a year or more than a specific season);
- *Temporary* or *Seasonal* (less than four but more than two months a year or during a specific season); and
- *Waterlogged.*

D. Leaf Type and E. Leaf Phenology

This level consists of the classifiers *Leaf Type* and *Leaf Phenology.* It can be entirely skipped. This option is included to allow the user to opt for a basic physiognomic-structural vegetation classification. The choice of the dominant *Life Form* will disactivate a number of choices at this level as a consequence of the conditions of the classification.

The classifier *Leaf Type* is subdivided into:

- *Broadleaved*: referring to trees and shrubs of the botanical group Angiospermae, with the exception of ginkgo (*Ginkgo biloba*), which belongs to the Gymnospermae taxonomically.
- *Needleleaved:* referring to trees and shrubs of the botanical group Gymnospermae (Ford-Robertson, 1971) carrying typical needle-shaped leaves.
- *Aphyllous:* this category encompasses plants without any leaves and plants which apparently do not have leaves in the common sense. In the first case, photosynthesis takes place through other organs, such as stems, branches and twigs; in the latter case the leaves are very short-lived or extremely reduced, to scales and thorns. Characteristic genera are *Casuarina, Euphorbia, Tamarix* and many others mostly found in arid and semi-arid regions (Kuechler and Zonneveld, 1988).

Leaf Phenology is determined from the general behaviour of woody plants through the year. A distinction is made between evergreen and deciduous:

- *Evergreen:* perennial plants that are never entirely without green foliage (Ford-Robertson, 1971).
- *Deciduous*: perennial plants that are leafless for a certain period during the year (Ford-Robertson, 1971). Leaf shedding usually takes place simultaneously and in connection with the unfavourable season (UNESCO, 1973).

The modifiers *Semi-Deciduous, Semi-Evergreen* and *Mixed,* as well as *Perennial* and *Annual,* are explained in Appendix A.

F. Stratification or Layering

The user can describe up to three layers of stratification (including the main layer) for *Terrestrial Vegetation* (A12) and up to two layers in *Aquatic* or *Regularly Flooded Vegetation* (A24) (see Appendix B). The users may be disappointed by the limited number of layers at their disposal, but the classifier *Stratification* should contribute to the structural definition of a vegetation class. This means that this classifier must cover all the possible combinations with the main *Life Form* selected and its *Cover* (e.g., if we can have layering for Closed Trees, the same must be valid for Closed or Open Shrubs or Closed Graminoids, etc.). The layering is an active component of the class set-up; it is not a mere descriptive (optional and unsystematic) item of the class. The proposed classification allows the user to first build up a land cover class with the use of the classifier *Stratification* and, where more

detail is wanted, add a users' description to the standard one, which may contain information on any additional layers/strata.

Some limitations in the use of the classifier *Stratification* have been introduced in order to avoid irrelevant (from the structural point of view) class combinations. The following examples will further clarify this concept:

- "Tree Savannah" is clearly defined by two main elements: a Herbaceous vegetation layer and a Sparse Trees layer. Thus, the Stratification of the two elements Herbaceous and Tree layer is crucial for the definition of this class.

- "Closed Forest" is clearly defined by the element of a Closed Trees layer. Limitations have been introduced (as will be explained below) for this class in the use of Stratification. It is not possible, in this case, to determine the presence of a Herbaceous layer because the classification rules set up for the Layering allow the user only to determine sub-layers of Trees and/or Shrubs. The determination of a Herbaceous layer would not contribute to the main structural meaning of the class as defined at the first level. The element Herbaceous layer can be added as part of the user-defined description of the class (see Legend - Edit).

The limitations introduced, as shown in the two examples above, are to avoid introducing elements not crucial for the determination of the structural aspects of a land cover class. These elements can be added in the class description in the Legend (see *Legend - Edit*). These limitations have the practical purpose of reducing the number of possible combinations of classifiers, which otherwise could lead to the creation of an even larger number of classes that yet would have the same structural meaning. All limitations in use of *Stratification* are built into the software application.

From the practical point of view in the use of the Stratification concept, it is important to recognize that two possible types of Stratification exist:

(a) where the second stratum consists of the *same Life Form* as the main stratum (e.g., trees-trees and shrubs-shrubs); and

(b) where the second stratum consists of a *different Life Form* (e.g., trees-shrubs).

The second case is quite straightforward and does not present any difficulty in the selection of classifiers. The first case needs additional explanation. In the case of a dominant *Life Form* of Trees with a second stratum of Trees, it is important that these layers are clearly distinguishable from one another (e.g., a second strata of *Trees Emergent* over a *Closed Tree* canopy; where these emergents must not be part of the discontinuity of the *Closed Tree* canopy but clearly a distinct layer). The sub-condition of *Height* will pre-set the available choices of Height for second and/or third layers/strata (e.g., main stratum of *Closed Low Trees* (3-7 m), the emergents to be defined in the second stratum cannot have the same height (option 3-7 m therefore not available) because the *Sparse Trees* of the second layer have to be taller).

The *Height* parameter explained above depends on the *Height* value chosen for the main stratum; it is not applied if the general *Height* class is selected. If the user selects the general *Height* class for the main stratum, then for subsequent strata the general *Height* classes are the only options available.

The main conditions applied for Stratification/Layering are the following:

(a1) Forbs and Graminoids are considered always together as Herbaceous.

(a2) For Trees, three strata including the main, can be considered (e.g., a main Closed Tree layer with a second lower Closed to Open Tree layer and a third Sparse Tree layer of emergents is called a "Multi-Layered Forest With Emergents").

(a3) When the main stratum is Closed Trees or Open Trees and there is a second layer of Sparse Trees then the Height of the second layer must be higher, i.e. emergent. If they are lower they are not considered as an independent stratum.

(a4) For Shrubs, the number of strata with the same *Life Form* is two, including the main stratum.

(a5) For Herbaceous, only one stratum is possible.

(a6) Lichens/Mosses are not described in the layering.

(a7) If the main stratum is Trees and the Cover is Open, then it is impossible to have the same *Life Form* with Cover Open To Closed with a different height as a second stratum (e.g., Open High Trees with Open Low Trees is impossible).

(a8) If the main stratum is Shrubs and the Cover is Closed or Open with the general option of Height, then it is impossible to have the same *Life Form* with Cover Open to Closed with a different height as a second stratum (e.g., Open High Shrubs with Closed to Open Low Shrubs is impossible). The only exception to this rule is when the second stratum consists of Dwarf Shrubs.

and

(b1) If the cover of the main stratum is Closed Trees or Closed Shrubs, then any Herbaceous layer is not considered or described (this can be added as a user-defined description).

(b2) Sparse Herbaceous is never considered as second layer except when the main layer is Sparse Trees or Sparse Shrubs (but it can be added as user-defined description).

(b3) If the main stratum is Shrubs or Herbaceous, only one layer of trees can be considered. This is linked with the criterion of dominance, as described earlier, because the Trees or Shrubs can be only Sparse.

(b4) Only two layers other than the main layer are considered for Terrestrial Vegetation (A12), and only one additional stratum for Aquatic or Regularly Flooded Vegetation (A24).

2.3.3.2 Cultivated and Managed Terrestrial Areas (A11 and A23)

Cultivated areas are often only described and classified by determining the crop species, the cultural practices and in some case land tenure information. This may result in descriptions like "rainfed agricultural area" or "state-owned rubber plantation." These descriptions are highly sectoral and do not address the needs of a wide variety of end-users. Another important aspect is that in the sectoral approaches the principle of having a high level of geographical accuracy is frequently lacking.

Description of agricultural areas in land cover terms should be exhaustive and neutral in the sense that the results may be used by many. Furthermore, these areas are primarily vegetated land cover types; thus their description should have a link to (semi-)natural vegetated land cover types at a certain level of detail (e.g., a user interested in trees because of the nesting prospects of a certain bird may not be directly interested in knowing if these trees are part of a crop or (semi-)natural vegetation). Furthermore, the focus should be on the definition of geographically well-defined classes, i.e., classes having a high mapability.

Therefore, the approach taken in order to enable a wide variety of users to employ the descriptions of cultivated areas is that of a basically physiognomic-structural classification. This means that at a high level of classification the cultivated area description is based on the structure of the vegetation, whereas at lower levels, with lower mapability, the focus is on description of the spatial and temporal dimensions. This type of description should, however, assure a high degree of compatibility with existing agricultural classification systems. This means that not only should the classes be compatible but also the method of deriving classes and their spatial and temporal dimensions (Duhamel, 1995). The spatial and temporal dimensions for cultivated areas clearly differ from (semi-)natural vegetation, as in most cases there is a constant flux in the observable cover.

Owing to this flux, the moment of observation of the land cover is very important, as the land might be ploughed, sown or harvested (with no crop actually visible), or a crop is clearly visible and different crop growth stages can be identified. These temporal dimensions influence the land cover but should not influence its description, because the area should be classified independent of the time of observation. It is for this reason that in the definition of *Cultivated Areas* provision is made for the fact that vegetative cover is not always present.

In the structural approach, physiognomy or *Life Form* is the principal classification criterion, followed by the vertical structure, the crop layering and horizontal structure, i.e., the Field Macropattern, of the area. This will result in detailed cover information that can be optionally combined with *Crop Type* as a specific technical attribute to establish a link with many current classification systems (Appendix B and C).

In the major land cover type of *Terrestrial Cultivated Areas and Managed Lands* (A11), *Managed Lands* form a separate category. They comprise land cover classes that are clearly vegetated and managed, though not with the intent of harvesting, as is the case for *Cultivated Areas*. The structural description of their cover in this classification may appear simplistic, but a further description in land use terms would render much more information. The description in cover terms will assure a high level of mapability, which can be freely combined with user-defined land use descriptors.

A. Life Form - Managed Lands

Managed Lands form a separate category inside the *Cultivated Terrestrial Areas and Managed Lands* (A11) and consist of one single classifier: *Life Form*. The Managed Land

Areas are described by the *Life Form* composition rather than description of the individual *Life Forms* of the vegetation. They are defined by specifying the occurrence of trees, shrubs and/or herbaceous life forms. Three options are available: *Parklands, Parks* or *Lawns.*

Managed Lands may comprise private gardens, public green areas, sport fields, etc. They are usually found in the (peri-)urban environment. This category may be further elaborated in future to include a wider range of classifiers for more detailed descriptions.

A. Life Form - Cultivated Areas

Two main aspects of the classifier *Life Form* should be taken into account:

(1) the concept of *Life Form* in this classification; and

(2) the determination of the dominant *Life Form.*

Careful determination of these two main aspects is important because the classification is set up in such a way that the choice of the main *Life Form* has consequences for the choices available at lower levels due to certain built-in conditions.

Life Form is defined by the physiognomy of the plants. Under *Cultivated Terrestrial Areas*, Trees and Shrubs are distinguished from Herbaceous plants, subdivided into Forbs or Graminoids. Under *Cultivated Aquatic or Regularly Flooded Areas*, only Graminoid and Non-Graminoid crops are distinguished. The following rule applies: those plants that belong to the Graminae family but have a woody appearance (e.g., bamboos) are classified as Herbaceous plants. This rule differs from the rules applied in Natural and Semi-Natural Vegetation (major land cover types A12 and A24).

For determination of dominance the following rules apply:

- The main criterion is the **uppermost canopy layer**. This means that the cover goes from Trees to Shrubs to Herbaceous/Forbs/Graminoids.

- This general condition is subject to a **sub-condition of "marginality"**, i.e. the crop should cover at least 15 percent of the area and/or should return the highest economic revenue.

These two rules are the main criteria for determining the main crop. There are no restrictions to possible crop *Life Form* combinations (in contrast to the description of (Semi-)Natural Vegetation, as explained in the next paragraph).

The *Trees* and *Shrubs Life Forms* can have two additional modifiers: Leaf Type (*Evergreen* or *Deciduous*), in combination with Leaf Phenology (*Broadleaved* or *Needleleaved*). The introduction of this modifier for these two *Life Forms* assures a link with the description of the natural vegetated areas.

B. Spatial Aspect – Field Size and Spatial Distribution

The second classifier that can be applied is *Spatial Aspect – Size*. This classifier often implies other aspects (e.g., land tenure, mechanization, land reclamation, etc.). In many classifications one find terms like "large-scale irrigated agriculture" or similar. This classification needs to be neutral in its land cover description without including ambivalent terminology. Therefore, *Spatial Aspect* has been selected as a neutral classifier. For mapping exercises, Spatial Aspect is an important aspect at the meso- or macro-level. Furthermore, it is an easily detectable characteristic (e.g., on aerial photographs and satellite imagery), i.e., it has good "mapability."

Field Size may differ according to biophysical conditions. Therefore, the quantitative values are indicative. The classifier is applicable at the level of the individual field and three categories are distinguished:

- less than 2 ha;
- 2 to 5 ha; and
- more than 5 ha.

This classifier can be skipped because size is a very subjective element.

Spatial Distribution is the horizontal pattern of cultivated fields in a certain area. It can be easily measured, taking the distance between one field and the next. A distinction has been made into three classes:

- *Continuous* describes a continuum of more than 50 percent of cultivated fields. In this case the land cover mapping unit may be single (inside the mapping unit the fields take up more than 80 percent) or mixed (the fields occupy 51-80 percent of the mapping unit) (see also Section 2.4.2). Generally, when the fields occupy 51-80 percent of the mapping unit, the area in between the fields can be considered by the user as part of the cultivated area, or the user can decide to make a mixed mapping unit, depending which land cover features the user wants to highlight.

- The Spatial Distribution is *Scattered Clustered* or *Scattered Isolated* when, within the cultivated field area, other land cover types are present. They are defined as follows:

    1. *Percentage of fields is more than 20 percent but less than 50 percent, it is Scattered Clustered*: this means that the resulting mapping unit is a mixed land cover class of a cultivated area with another land cover class. If the unit is composed of two land cover classes the cultivated area class is always the secondary class in the mixed unit, and both components need to be defined in the legend (e.g., 60 percent of semi-natural vegetation and 40 percent of fields).

    2. *Percentage of fields is more than 10 percent but less than 20 percent it is considered Scattered Isolated*: this means that the resulting mapping unit is a mixed land cover class where the dominant class is not this one. It is the only case where a class comprising less than 20 percent is present in a mixed mapping unit (see Section 2.5).

C. Crop Combination (A11) and E. Crop Combination (A23)

At the second level the *Crop Combination* is specified for the Cultivated Terrestrial Areas and at the fourth level for Aquatic or Regularly Flooded Cultivated Areas. If there is more than one crop, the crops present can be specified together with details of the possible overlap in growing period between the main and secondary crops (A11) or the type of setting the crops are growing in (A23)[1]. The order in which an additional crop is specified, follows the same condition as stated above.

- The dominance is determined by the **main criterion of the second-uppermost canopy layer**. This means that the cover goes from Trees to Shrubs to Herbaceous/Forbs/ Graminoids.

- This general condition is subject to a **sub-condition of "marginality,"** i.e. the crop should cover at least 15 percent of the area (but less than the main crop) and/or should return the second highest economic revenue.

It is important to note that the classifier *Crop Combination* can also be skipped by the user because of the apparent difficulty in determining the classifiers correctly. This skip function will then permit the user to continue the description of the main crop at the third level. This function is unavailable in A23 because it is the final classifier to be determined.

C. Water Seasonality (only for A23)

The second level classifier *Water Seasonality* of Aquatic or Regularly Flooded Cultivated Areas describes the duration of water on or near the surface during the main crop cultivation period. If any additional crops are cultivated after, or in overlap with, the main crop the period of water at or near the surface for these crops should be neglected.

D. Cover-related Cultural Practices – Water Supply and Cultivation Time Factor (A11)

At the third level of classification the classifier *Cover-Related Cultural Practices – Water Supply* is determined. The options *Rainfed Agriculture, Post Flooding* and *Irrigated Agriculture* for Cultivated Terrestrial Areas have implications for the options available under *Cultivation Time Factor. Post Flooding* cultural practices are not possible in a *Permanent Cultivation* system. It is also obvious that the dominant crop determined will have implications for other classifiers (e.g., a Tree Crop will result in a Permanent Cultivation system).

A Permanent Cultivation system in combination with either a Trees or Shrubs *Life Form* designates what is commonly known as plantations and orchards (e.g., a forest plantation or a coffee plantation). However, these names do not occur *per se* in this classification system. In combination with Crop Type, a link to current systems can be made and to commonly used names such as "plantation" (e.g., the combination of *Shrub Crop* and *Crop Type: Tea* covers "Tea Plantation," while *Tree Crop* and *Crop Type:* Hevea *spp.* refers to "Rubber Plantation").

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[1] If there is more than one growing season in the area and multiple crops are grown in the major season, the user is advised to limit the description of additional crops to one instead of two and to use the second additional crop for description of the main crop in the second season.

D. Cover-related Cultural Practices – Fallow Period (only for A23)

Cover-Related Cultural Practices – Fallow Period is the third level classifier for Aquatic or Regularly Flooded Cultivated Areas. It has two subdivisions: *Relay Intercropping*, and *Sequential*. They refer to the practices that occur **after** harvest of the main aquatic crop (see also Appendix A). These practices may not relate to the same Aquatic or Regularly Flooded environment of the main crop.

2.3.4. Concepts for *Primarily Non-Vegetated Areas*

Areas primarily characterized by a cover other than vegetation fall into two categories: those with a non-vegetal cover and those with no cover at all. The latter is a category that describes the land surface rather than any cover of the land but which has been included here, as explained earlier (see Section 1.1).

The approach adopted for describing *Primarily Non-Vegetated Areas* is, as for Vegetated Classes, a "structural-physiognomic" approach, that is the physiognomy, the cover (i.e., density) and structure are used as parameters. The classifiers *Surface Aspect* (*Artificial Surfaces* and *Bare Areas*) and *Physical Status* (*Artificial and Natural Waterbodies, Snow and Ice*) can be regarded as descriptors of the physiognomy of the materials, like *Life Form* for vegetation. The further classifiers and modifiers of Bare Areas and Artificial Surfaces contain elements of *Cover*, as for Terrestrial Vegetation, whereas the *Water Persistence* classifier is similar to *Water Seasonality* in Aquatic Vegetation (Appendixes B and C).

2.3.4.1 Artificial Surfaces and Associated Areas (B15)

Areas with an artificial cover resulting from human activities are described in most classification systems in terms of use, whereas the description of cover is equally important. An example is urban areas where the surface generally consists of impervious materials. This type of impervious surface greatly influences run-off and the peak flow characteristics of water. Another example is tarmac roads in hilly terrain, where road constructors need to carefully plan for the discharge of excess water that, in poor designs, may lead to disastrous forms of erosion.

The Associated Areas are mainly domains where the original surface is removed, such as extraction sites, or where materials have been deposited on top of the original surface, such as waste dumps and other type of deposits.

The characteristics of the cover of the surface are crucial in the land cover description and therefore embody the main classification concept. This major land cover type is classified depending upon the Surface Aspect. A category for the Built-Up Object can be specified using the scroll list (e.g., cities and towns, roads, open mines, official waste dump sites, etc.).

A. Surface Aspect

The *Surface Aspect* distinguishes two main classes, with one class having two levels with an increase in detail. A much more detailed class description can be made using the modifier options. These modifiers are explained in terms of cover rather than land use terminology.

The *Artificial Surface* areas can be further defined according to the shape and density of the artefacts.

2.3.4.2 Bare Areas (B16)

Areas which are primarily bare are usually described by geologists, soil scientists or geomorphologists (using technical terms like granite rock, rendzhina, sand dunes, inselberg, tor, etc.). This type of description is highly technical, and may be difficult to understand for users with a different background. An approach is therefore needed which describes the type of material on the surface, with additional options to go into more detail, in combination with elements describing either some specific properties (physical or chemical) of the surface material, or describing some specific forms. Specific forms implies that the surface may consist of shapes that form a pattern at the macro-level. The focus of the cover description is on the surface and not on the subsoil.

The major land cover type *Bare Areas* is, therefore, described mainly by the appearance of the surface. The concept adopted describes the aspects of the cover: whether it is consolidated or not, and of what kind of material it comprises (e.g., rock, sand, etc.), and which may be combined with Macropattern. The more discipline-related descriptors for geology, landform and soil are available as attributes and can be used to link the land cover description to the technical disciplines.

A. Surface Aspect

The *Surface Aspect* describes the surface of the Bare Area at two levels, with an increase in detail. A further specification can be made by using one of the modifiers. These modifiers specify some physical or chemical properties.

B. Macropattern

The *Macropattern* describes the pattern of the surface. This classifier is linked to the *Surface Aspect* because a *Macropattern* can only be of the same material as the surface described. Hence the choice made under *Surface Aspect* may disable certain choices in this classifier. Two types are distinguished, namely *Bare Soil* and *Loose and/or Shifting Sands.*

2.3.4.3 Artificial and Natural Waterbodies, Snow and Ice (B27 and B28)

The two major land cover types describing water surfaces or other physical appearances of water, *Artificial Waterbodies, Snow and Ice* (B27) and *Natural Waterbodies, Snow and Ice* (B28) are described by taking into account their temporal aspect. Water, snow and ice may not be present all year round and therefore it is also important to know what the cover is when they are absent. This temporal aspect should not influence the classification results because classification by default is independent of temporal change.

In most existing classification systems these land cover types are only briefly described in terms of cover, with no additional information. The concept adopted by this classification puts more emphasis on the temporal aspect.

The major difference between these two major classes is that *Artificial Waterbodies, Snow and Ice* are surfaces in places where, under natural circumstances, no water, snow or ice surface would exist. Therefore these surfaces are the result of an artefact, such as the construction of a dam, the making of artificial ice or snow, etc.

A. Physical Status

The *Physical Status* describes in which form water is found. Three options are available: Water, Snow or Ice. Depending on the choice made here, other classifiers at lower levels may be disabled. For water and ice a further specification can be made into Flowing or Standing Water and Moving or Stationary Ice.

B. Persistence

Persistence, i.e., the duration that Water, Snow or Ice covers the surface, is described. If Water, Snow or Ice is present for nine months or less per year, the surface then exposed can be further specified.

C. Depth

The *Depth* can be described because this is directly related to cover aspects. The proposed classifier has not been given a lot of detail because the most important feature to be determined is whether it is deep or not, i.e., whether it is shallower or deeper than 2 m. This limit has an ecological meaning as it is the maximum rooting depth for the great majority of aquatic plants (Cowardin *et al.*, 1979).

D. Sediment Load

The suspended *Sediment Load* in the water influences the cover and implies other environmental aspects, such as upstream erosion and downstream sedimentation. It also influences the aquatic fauna and flora. It is a relatively easily observed characteristic of the water, but difficult to measure as it fluctuates. Therefore the subdivision has not been given great detail.

2.3.5 Environmental and Specific Technical Attributes

The pure land cover classifiers can be combined with so-called attributes for further definition (see also Section 2.3.2.) of the land cover class. These attributes are intended to be used as a further characterization of the land cover itself rather than to add a new data layer. Application of the attributes in the full legend, when all classes would have the same set of attributes, they could be used as a separate layer in the database. Two types of attributes, which form distinct levels in the classification, are distinguished:

Environmental Attributes: attributes that are not inherent features of land cover but may influence the land cover.

Specific Technical Attributes: attributes referring to the technical discipline of the major land cover type.

2.3.5.1 Environmental Attributes

L. Landform

Land forms are described first and foremost by their morphology, and not by their genetic origin or the processes responsible for their shape. The dominant slope is the most important differentiating criterion, followed by relief intensity (Appendix A).

This attribute can be applied to all classes except Artificial Surfaces and Artificial and Natural Waterbodies, Snow and Ice. The attribute consists of two different levels, that is major land form and slope class according to the Soils and Terrain (SOTER) methodology (UNEP/ISSS/ISRIC/FAO, 1995).

M. Lithology

The lithology can be described based on the geological parent material and the age of it. The options were devised by Dr S.B. Kroonenberg, Delft University of Technology (*pers. comm.*, 1998). Three major groupings are distinguished and further subdivided (see Appendix A).

N. Soils

For the *Primarily Vegetated Areas*, the user can describe first the soil's Surface Aspect, followed by a detailed description of the soil profile according to the Revised Soil Legend (FAO, 1988). For *Bare Areas* (B16) only the soil profile description is applicable because the soil surface aspect is a classifier of this major land cover type.

O. Climate

The concept adopted to add climatic parameters to the land cover classes is from De Pauw *et al.* (1995). The revised Length of Growing Period (LGP) approach gives recognition to the relevant climatic constraints in any major region of the world. The combination of Thermal Classes and Moisture Classes gives the climate. No conditions have been pre-set.

P. Altitude

This attribute can be used in all major land cover types. The classes of this attribute are a proposal and can be further subdivided by using the possibility available in the Legend Module to create a user-defined attribute (see Section 5.2.5).

Q. Erosion

In the description of *Erosion* in the land cover, emphasis is given to accelerated or human-induced erosion. Human-induced erosion is often the result of irrational use and poor management, such as incorrect agricultural practices, overgrazing or overexploitation of the (semi-)natural vegetation. These practices result in a cover type with specific features. Most of the erosion can be classified as either Water or Wind erosion and deposition, with the Mass Movements as a third major category. Further subdivision can be made by using the User-defined Attribute option in the Legend Module.

This attribute is applicable in all *Primarily Vegetated Areas and Bare Areas* (B16).

R. Water Quality (only for A24)

This attribute is only applicable in *(Semi-)Natural Aquatic or Regularly Flooded Terrestrial Areas* (A24). It can be used to specify the salinity of the water (measured in ppm of TDS) according to Cowardin *et al.* (1979).

U. Scattered Vegetation (only for B16, B27 and B28)

This attribute is applicable for *Bare Areas* and *Artificial and Natural Waterbodies, Snow and Ice* (e.g., sandy riverbed with scattered vegetation) to indicate that less than 4 percent of vegetation is present. In the case of the presence of Lichens and/or Mosses, they should be less than 20 percent (see Appendix A).

W. Crop Cover/Crop Density (only for A11 and A23)

This attribute is only applicable for the *Cultivated Areas*, both *Terrestrial* and *Aquatic or Regularly Flooded*. This attribute gives information on the density of the permanent crops, (e.g., Trees and Shrubs), or the cover of the temporary life forms (e.g., Herbaceous, Forbs and Graminoids). This information is an indicator of the success of crop establishment and hence its possible yield.

The density has not been used as a land cover classifier, as for (semi-)natural vegetated areas, because it normally would not add any useful information to the land cover class. The density is related to the planting distance of the crop, which differs according to crop (e.g., olive trees versus maize). However, it is a useful attribute when describing a cultivated area which does not have the expected density of the crop (e.g., in marginal areas).

2.3.5.2 Specific Technical Attributes

These attributes are related to the technical discipline associated with the major land cover type: thus, for (Semi-)Natural Vegetated, areas the Floristic Aspect can be described; for Bare Areas, the Soil Type (as discussed under *N. Soils*); for Cultivated Areas, the Crop Types; and for Artificial and Natural Waterbodies, Snow and Ice, the Salinity.

S. Crop Type (only for A11 and A23)

The *Crop Type* can be specified according to the major groupings used for the FAO Production Yearbooks. If a *Crop Type* is not present, it can be defined and added under the header *Other* in the boxes which open upon clicking. Furthermore, the name of the crop has to be linked to the dominant, second or third crop choices, if not the entry is not saved. Thus, a maximum of three names can be specified.

T. Floristic Aspect (only for A12 and A24)

This attribute has two major divisions: if the name is derived from a single plant species or a group of plants. In the first option, a further subdivision is possible into *Dominant Species* (Height, Cover or combination of both) and *Most Frequent Species.* The second option is subdivided into: *Plant Groups* (e.g., Braun-Blanquet) and *Plant Groups Derived Without Statistical Methods* (e.g., same ecological significance, same geographic distribution, same dynamic significance, etc.). The specific name of the *Floristic Aspect* can be added with the User-Defined Attribute option in the Legend Module.

V. Salinity (only for B27 and B28)

The *Salinity* of the water can be specified for *Artificial and Natural Waterbodies.* Three main classes are distinguished, based upon Cowardin *et al.* (1979).

2.4 THE ADVANTAGES OF THE ADOPTED METHOD

2.4.1 Advantages from the conceptual point of view

It is a real *a priori* classification system in the sense that, for the classifiers considered, it covers all their possible combinations. Some particular combinations are excluded, due to conditions that are elements of the classification system. In this case the type of combinations and the conditions, i.e., the reasons, for this "exclusion" are clearly listed and explained.

A given land cover class is clearly and systematically defined making a clear and unambiguous differentiation by use of the classifiers as follows:

- pure land cover classifiers (each one ordered from general to more specific level);
- environmental attributes (e.g., Climate, Landform, Geology, etc.); and
- specific technical attributes (e.g., Floristic Aspect for (Semi-)Natural Vegetation).

This system avoids unclear definitions (e.g., "tropical rain forest" where a climatic attribute is used for a floristic description).

The classification is truly hierarchical. The class' hierarchical arrangement is a basic component of the mechanism of the class formation. The difference between a land cover class (at a more general level) and a further subdivision of it is given through the addition of new classifiers (or a more detailed level of the one forming the previous class). The more classifiers used, the greater the detail of the land cover class defined.

The classes derived from the proposed classification system are all unique and unambiguous, due to the internal consistency and systematic description of the class as a basis for objective and repeatable classification. Correlation studies between classifications show that in many cases definitions of the class names are often either unclear or unsystematic, or both, due to the fact that in traditional classification and legends the "meaning" of a class is derived only from its general description. Such a descriptive text is very often unsystematic, and as a result in many cases there are insufficient details to define strict boundary conditions. The classes are therefore open to misinterpretation and lack internal consistency. With the present classification the user's primary descriptive tool is the Boolean Formula of all classifiers used to build the class; this cannot be anything other than a systematic description of the class. In addition to this, the traditional class description is used. A strict class boundary definition and internal class consistency are inherent to the method.

LCCS is designed to map at a variety of scales, from small to large (see Section 3).

For two main reasons, the classification can be used as reference classification:

- the classification contains a large number of classes (the classes of the existing classifications and legends can always be accommodated); and

- emphasis is on a set of classifiers rather than just a name, which allows easy correlation even when a range of values, such as the percent of cover of a given life form, does not fit with the proposed value; the dissimilarity is clear and remains limited to only a portion of the elements forming the class. This event however should be extremely rare due to the different levels, from more general to more specific, forming a single type of classifier.

2.4.2 Advantages from the practical point of view

The specific design of the classification allows easy incorporation and integration into GIS and databases. The mechanisms of how the classes are built up (see Section 2) facilitate overlay procedures.

It will produce a real multi-user database. Despite the high demand for natural resources information, many databases are not developed to meet multi-user requirements. This is shown by the fact that very often the number of real users is often a small portion of the potential ones. An important cause is the inherent rigidity of the natural resources information (i.e., land cover) of the databases. Two cases are typical:

- the original project is very specialized (e.g., vegetation ecology), and hence the class name and description of the resulting legend are difficult to understand by other users (such as rural planners, statisticians, etc.); or

- the original project is not specialized, and so the classes or the class descriptions are too generic to be used by specialized disciplines.

The ways in which current classifications determine the classes (names and generally a broad description) do not allow a great deal of flexibility of use by the final user. The present classification system assumes two types of final users:

- the one that uses the classification to built up the database (the user basically doing the interpretation activity); and

- the one that is the final user of the database created.

The system obliges the first user (the database builder) to follow specific rules in the combination of classifiers (to assure standardization and comparability of the data set) but allows the database user (see Section 3) to define freely the set of classifiers with which they wish to re-aggregate the original polygons of the database. Because the class definition is linked with the classifiers' Boolean Formula, this is a straightforward process. Of course, the number of potential recombination of classifiers is extremely large, and some combinations may be illogical, but this respects the concept of multiple users, each with their very specific needs.

For interpretation purposes, the advantages are:

1. It is highly flexible, responding not only to the information available or gathered in a given area, but also to the time and budgetary constraints of a project. This means that within one land cover map, mapping units will contain the maximum available information, but that the quantity of information may differ between the mapping units. This will not affect the homogeneity of the resulting map. It will be possible, for instance, to have within the same map, in a certain geographical area polygons of a class formed with a certain number of classifiers (a high number as here more ancillary information is available), while, in another part, polygons where the same type of class will have fewer classifiers. It will always be possible to compare the two classes.

2. It rationalizes the field data collection. Because the classes are defined by a combination of classifiers, field surveyors should detect the single classifiers and not deal with the final class name. This means that the field survey can be done independent of, or parallel to, the interpretation process.

3. It facilitates standardization of the interpretation process, contributing to its homogeneity. Despite the huge number of classes the interpreter can generate to fit the land cover variations, one is dealing only with a limited number of classifiers. So one does not need to scroll inside a big, obscure list of class names but must simply aggregate a limited number of well-defined classifiers. This will also reduce heterogeneity between interpreters and between interpretations over time.

4. It allows the building up of a new procedure of accuracy analysis of the result. Until now, accuracy analysis was done for single classes; henceforth it will be possible to assess the accuracy not only for the entire class but also for each of the classifiers forming the specific class. This will give a high flexibility to finalization of the classes. If, for instance, a class formed by five classifiers shows an accuracy of 60 percent, which is too low according to the established standard, then by looking at the individual classifiers forming this class the user can analyse the contribution of each individual classifier to the overall class accuracy. If, in the example, the first four classifiers have an accuracy of 90 percent while the fifth classifier only 60 percent, the user may decide to eliminate this last and less accurate classifier in order to have a final class with less detail but with a higher accuracy.

2.5 FROM CLASSIFICATION TO LEGEND

Classification is an abstract representation of the situation in the field using a particular set of diagnostic criteria, whereas a legend is the application of the classification's abstract design in a particular area using a defined mapping scale and a particular data set. This transition implies establishment of specific conditions not present in the classification concept (e.g., Minimum Mappable Area and Mixed Mapping Units). Because one of the ultimate goals of this classification is to provide a useful tool for mapping exercises, these conditions will be discussed here even if they are not strictly appropriate to the main subject of this chapter.

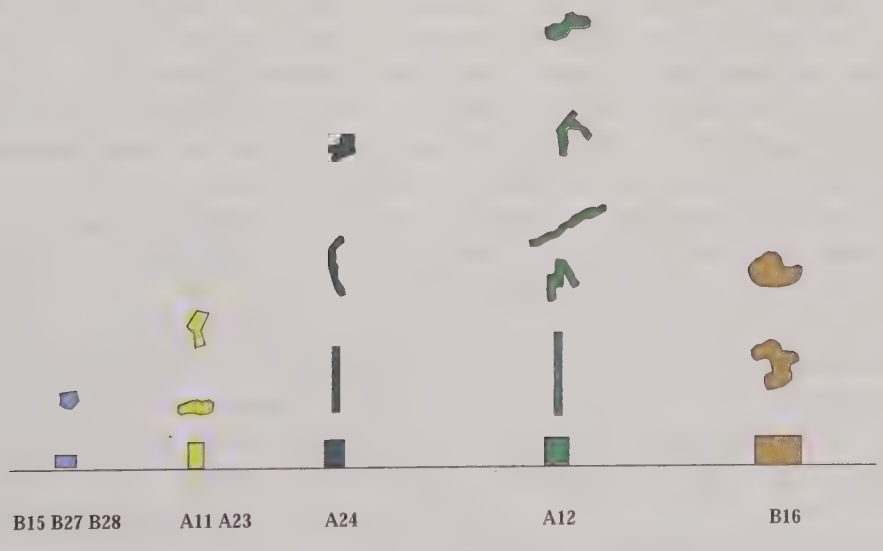
2.5.1 The *Minimal Mappable Area* concept

The *Minimal Mapping Area* is a concept applied by cartographers when addressing the smallest area that can be shown on a map. This concept is therefore scale-dependent and not related to classification. However, the issue is addressed here as it usually poses problems.

The concept of one single mappable area is generally applied. Historically, the cartographer determined one particular minimum size of area to be represented on the map. This was applied to all classes contained in the legend. The disadvantage of this method is that classes with a difference in importance would follow the same rules. It would have been more logical to define a set of different sizes for the various features with differing importance (Di Gregorio, 1991).

The flexibility of this current classification allows the introduction of the concept of a variable minimal mappable area. Thus, the user can relate the size of the minimal mappable area to the eight major land cover types from which the classes are derived (Figure 10).

FIGURE 10.
Example from the East Africa Project, with variable minimal mappable areas (not at original scale).



2.5.2 The Occurrence of Mixed Mapping Units

In the classification system, all classes are unique and no Mixed Mapping Units are considered. Mixed Mapping Units are cartography related. However, the user can go from a more general to a more detailed level of definition of a class. If for instance the classifier *Woody* is used, this implies that an intricate mixture of trees and shrubs is present in which neither is clearly dominant. This results in a mixture of two life forms but not in a mixed land cover class. A Mixed Mapping Unit in the legend is always characterized by two, or a maximum of three, separate single land cover classes as defined in the classification system. The conditions governing the utilization of mixed mapping units are that within the minimal mappable area, two or more land cover classes are present, which can be:

(1) in a spatially separate entity (e.g., patches of agriculture fields inside a forest); or

(2) in an intricate mixture (e.g., rainfed cultivated fields with Baobab woodland).

The latter is applicable only if a more general definition of the class (as explained above) is not appropriate.

In the case of spatially separate entities of two or more classes, the general criteria proposed is that the cover of each one of the class considered must be more than 20 percent (and consequently less than 80 percent) of the mapping unit. The limit of 20 percent is thus the threshold of "visibility" of a class in a Mixed Unit. The only exception to this rule is in the major land cover type of *Cultivated Areas*, where the use of the option *Scattered Isolated* of the classifier *Spatial Distribution* goes from 10 to 20 percent (see Section 2.4.2).

The sequence of the class names in a mixed mapping unit represents the dominance (e.g., for *Forest/Cultivated Areas,* Forest is more than 50 percent and less than 80 percent, whereas Cultivated Areas is less than 50 percent but more than 20 percent). A Mixed Mapping Unit can contain a maximum of three classes.

In the particular case of classes belonging to the major land cover categories *Cultivated and Managed Terrestrial Area(s)* (A11) or *Cultivated Aquatic or Regularly Flooded Area(s)* (A23), the user has an additional means to create a Mixed Mapping Unit. The classification system offers the possibility to create a so-called "Temporal Mixed Unit". Such a unit is used to describe the situation were in different years, different types of cultivation are executed in the same field (i.e. the mapping unit). This is the case when the user has, for example, a situation with cultivated fields of paddy rice in one year (e.g., when there is sufficient rainfall) followed by a terrestrial crop in the subsequent year(s) (e.g., when rainfall is poor). This particular type of Temporal Mixed Unit shows often a cyclic, almost customary, alternation of different crops in subsequent years (e.g., generally an Aquatic crop followed by Terrestrial crops, or an Irrigated crop followed by Rainfed crops, etc.). It is important to note that **the alternation of crops should be considered only when this occurs on an annual basis**. The combination of different crops in the same growing period is an option already considered in LCCS' class creation (see the classifiers related to Crop Combination in A11 and A23). However, because of the specific nature of this type of Mixed Unit, that occurs only where crops are growing, the **classes composing such a mixed unit can only be those of Cultivated Area(s)**.

- PART B -

Land Cover Classification System: User Manual

For software version 1.0

3. INSTALLATION

A dedicated software application has been built between the set of databases holding the numerous potential land cover classes formed by selection of the classifiers, modifiers and attributes available, as well as the various rules and conditions. The options to form land cover classes in the classification system are manifold and the software application makes any of these classes easily retrievable.

This section of the User Manual will cover:

- hardware and software requirements;
- installation procedure; and
- directory structure.

Before trying to install the Land Cover Classification System, ensure the PC meets the requirements specified below.

Please note that LCCS comes as a run-time software application; therefore it is not necessary to have ACCESS 97 installed on your computer.

System Requirements

Hardware:

- Pentium processor
- 8 MB RAM (16 MB or more recommended)
- Hard disk with at least 25 MB of free space
- The screen size can be variable

Operating System:

- Windows95/98, or Windows NT

Installation Procedure

LCCS comes as a Run-time version. The users have to follow the regular installation sequence for Windows-based programs.

For Windows95/98, and NT users, the procedure is as follow:

(1) Insert the CD-ROM in your CD-ROM drive (in most cases D:)

(1) Click on Start

(2) RUN

(3) type *D:setup*

After having completed this step, a guided set-up procedure is activated. It is highly recommended that its proposals be accepted regarding the installation directory and naming of new program groups.

At a certain point in the set-up procedure, an MS-DOS window is opened where the user has to touch a button to proceed. After completion this window can be closed a window with the message "*Land Cover Classification System Setup was completed successfully*" will be displayed. Click the *OK* button to exit the set-up.

At the end of the set up, a new sub-directory C:\LCCS is created and a new Land Cover Classification System icon is added to the Windows Program Manager.

Directory Structure

The installation looks for the following directory structure and – if necessary – creates it:

- C:\LCCS contains the database software and the databases as such.
- C:\LCCS\DOCS contains the WinWord documentation files for LCCS.
- C:\LCCS\IMAGE contains the example image files delivered with LCCS.

4. OPERATION

Though no previous knowledge of Microsoft Windows is required to operate LCCS, there are some Selection Techniques and Screen Objects the user should become familiar with in order to be able to use the LCCS Actions Panel without problems.

Selection Techniques

- *Mouse click:* moving the arrow shaped mouse cursor to an object (such as a button or a symbol) and pressing the mouse's left button once.

- *Double click:* as above, but pressing the left mouse button rapidly twice.

Screen Objects

Typical objects in LCCS, through which the user communicates with the program by making a selection or triggering an action, are:

- *Buttons*: clicking when the mouse arrow is over a button object triggers the action usually displayed as the button's label (like making a menu choice or quitting a program).

  Buttons can take 3 different states:

  Enabled but not activated: button takes a risen appearance.

  Enabled and activated: button takes a sunken appearance.

  Disabled: a button that is disabled cannot be activated; its label shows as lighter grey.

- *Combo Boxes*: these boxes let the user select from a list of items. By typing the first few characters of a possible choice in the box a matching entry will be displayed and can be selected by pressing <Enter> or by double-clicking the requisite list item. A list of entries unfolds upon clicking the down-arrow at its right hand side. An entry can be selected by double-clicking on it. Should the list be longer than the size of the box, vertical scrollbars are displayed at the right hand side of the box, inviting the user to click on the up or down arrows to see further entries in the list box.

- *LCCS Sub-menus:* like the Main Menu screen, the LCCS sub-menus let the user branch to further options by clicking on one of the menu buttons.

- The *F1 Key/Help*: pressing the F1 key in any of the forms/screens of LCCS brings up a context-sensitive Help screen. The effect of pressing the F1 key is the same as clicking on the 'Help' button.

The Classification Module Actions Panel appears in the majority of forms/screens of this module. This panel contains 10 buttons that trigger different actions (Figure 11).

FIGURE 11. **The Actions Panel in the Classification Module.**

The buttons of the Actions Panel trigger the following events:

- *End Classification*: This button opens a box containing the question "Do you really want to quit Classification?" with the options Yes or No.
- *Previous Form/Screen*: This button brings the user back to the previous form/screen, with all previously selected buttons visible.
- *Legend Menu:* This button brings the user to the Legend Module menu.
- *Image Database:* This button activates stand-alone commercial public domain software for image (e.g., satellite imagery) display.
- *Show Classifier Codes*: This button opens a window with the relevant classifier options and their corresponding codes. The Close button can be used to close this window.

- *Context-sensitive Help*: This button opens the Help facility of the current major land cover type the user is in, and which contains all definitions and guidelines for the correct use of the classifiers, modifiers and attributes.

- *Show Class*: This button opens a new window in which the classifier, modifier and attributes codes used can be viewed, as well as the name of the land cover class. The button in the lower right-hand corner can be used to close this window.

- *Write Class to Legend*: This button opens a window in which the user has to select one of its options before the class can be successfully written to the Legend Module (for further explanation see Section 5.2).

- *Next Form/Screen*: This button brings the user to the next level of the classification and is only enabled when all available classifiers in the form have been determined. This button is not available for environmental and specific discipline related attributes.

The buttons are in the enabled position when the action they trigger is valid. *The Show Class* button in the enabled position indicates that a land cover class has been formed, that is the minimum set of classifiers to define a land cover class has been determined.

In the Legend Module the screen objects consist of buttons that may or may not be followed by a combo box or sub-menu with several options, as described earlier.

For the main Legend menu options *Display, Standard Description* and *Classifiers Used,* a report will be shown which can be printed. The same applies for *Similarity Assessment* in the Translator Module.

In the Translator Module the selection technique consists of clicking on button objects or highlighting a selected item by clicking once on it (especially in list boxes).

5. THE PROGRAM MODULES

Each of the four modules will be discussed in detail regarding its purpose, the options available and the links with other modules of the software.

5.1 CLASSIFICATION

5.1.1 Purpose

The purpose of this module is to define a land cover class according to two main phases:

- An initial Dichotomous Phase, where the user derives the main land cover type. For this phase at each level a choice is made between two alternatives, hence the term *dichotomous*. After having determined the main land cover type, the user can proceed to the next Phase, but the user can also define a generic class using only this initial phase.

- A subsequent Modular-Hierarchical Phase, where a land cover class is defined by determining one classifier at a time. The classifiers available are tied to the main land cover type. In this Phase, the selection of one classifier at a high level may have consequences for the options available at lower levels. The system is constructed in such a way that choices no longer valid in connection with a chosen classifier at a higher level become inactive.

At any level within these Phases the user can ask for the land cover class and store its Boolean formula, numerical code and class name in the module called "Legend."

5.1.2 Dichotomous Phase

In the Dichotomous Phase the user can select the major land cover category to which the land cover belongs. There are two ways to proceed through the options, to either:

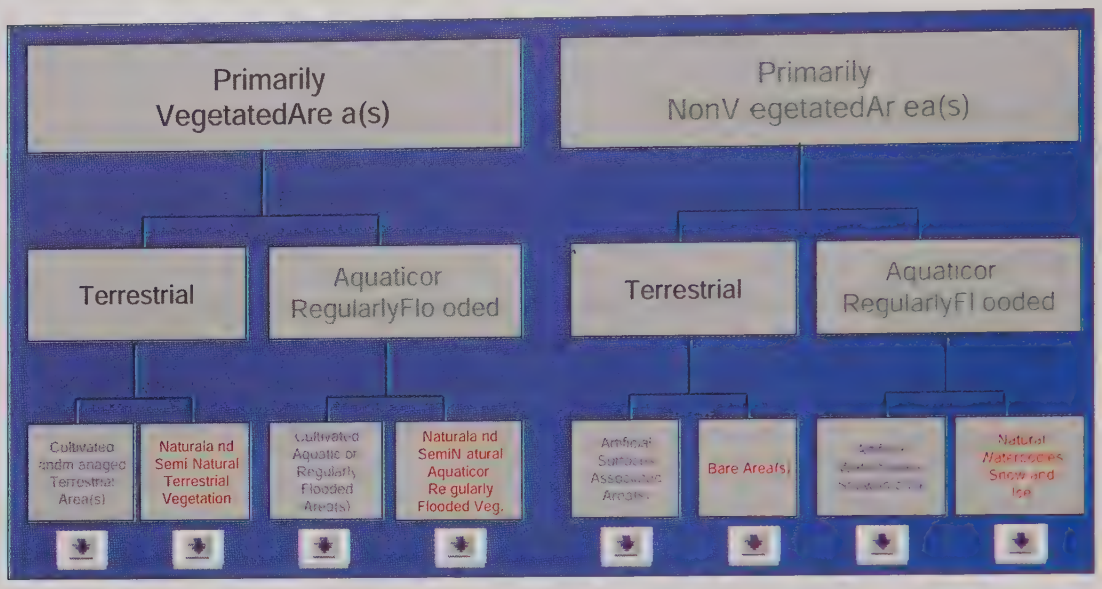
- start at the top of the key and determine at each level which option is valid by clicking the appropriate button; or

- identify immediately to which major land cover type the class will belong and by clicking directly on the button with the arrow immediately below the button with the major land cover type name.

Having determined the major land cover type (Figure 12), the Dichotomous Phase is completed and the user automatically enters the next phase. A pop-up screen will inform the user of the change of Phase.

If the level of information needed or available to determine a land cover class is very limited, the user can select the appropriate choice(s) in this phase and a land cover class will be defined. This class will consist of a Boolean formula, a standard name and numerical code. This class can be stored in the Legend Module (see Section 5.2). Classes thus defined are broad categories because of the limited number of classifiers used. For more detailed definition of classes the user should apply the classifiers of the Modular-Hierarchical Phase.

FIGURE 12.
The Dichotomous Phase with the classifier options *Primarily Vegetated - Terrestrial - Natural and Semi-Natural Vegetation* selected.



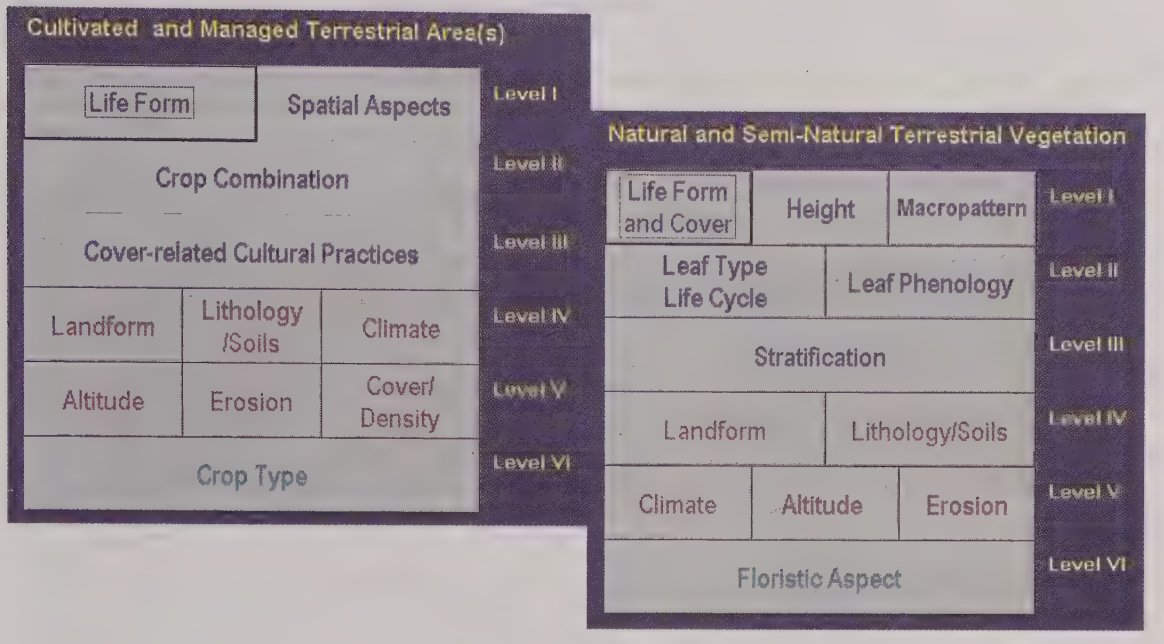
5.1.3 Modular-Hierarchical Phase

The Modular-Hierarchical Phase is a phase where the set of available classifiers is tailored to the major land cover type. This means that the type, amount and hierarchical arrangement of classifiers will differ from one major land cover type to an other.

In each module, however, three groups of classifiers and attributes are available and they are always presented in the same hierarchical order. Each type of classifier and attribute is also presented in a different colour on the video screen (Figure 13). A distinction is made between:

- pure land cover classifiers at the top levels of the module;
- environmental attributes at the intermediate levels; and
- specific technical or discipline-related attribute at the bottom level.

FIGURE 13.
Example of the classifiers and attributes of two major land cover types: *Cultivated and Managed Terrestrial Areas* (A11) and *Natural and Semi-Natural Terrestrial Vegetation* (A12).



Pure Land Cover Classifiers

The difference between these classifiers and the attributes is that the land cover classifiers are strictly hierarchically ordered. One cannot skip a classifier and go on to the next one unless this possibility is provided for by the program, as occurs with "Semi-Natural and Natural Vegetation" and "Cultivated Terrestrial Areas and Managed Lands". The user must proceed step-by-step in order to develop the structural-physiognomic concept (see Sections 2.3.4.1 and 2.3.4.2).

The classifiers are also ordered according to their mapability. The classifiers at a high level have a higher mapping accuracy than classifiers from lower levels, which means that they will contribute more to establishing clear and precise boundaries between different land cover classes than will lower-level classifiers. If a classifier cannot be determined, the user can stop.

Definition of the land cover class results in:

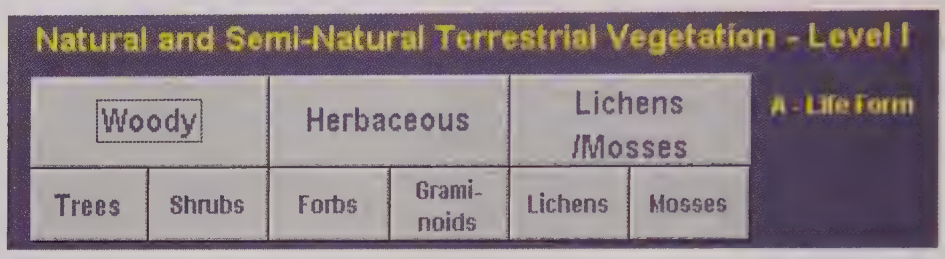
- a unique Boolean formula (a coded string of the classifiers used);
- a standard name (nomenclature); and
- a unique numerical code that may be useful in GIS applications.

Both the numerical code and nomenclature name can be used to automatically generate a Legend (see Section 5.2).

The user will start to identify any land cover class using the pure land cover classifiers. A minimum number of these classifiers need to be determined before the user is allowed to combine these classifiers with any of the attributes. If the minimum requirement for classifiers has been satisfied, the button for proceeding to the environmental attributes will be enabled, as well as the buttons to show the class and save it to the Legend.

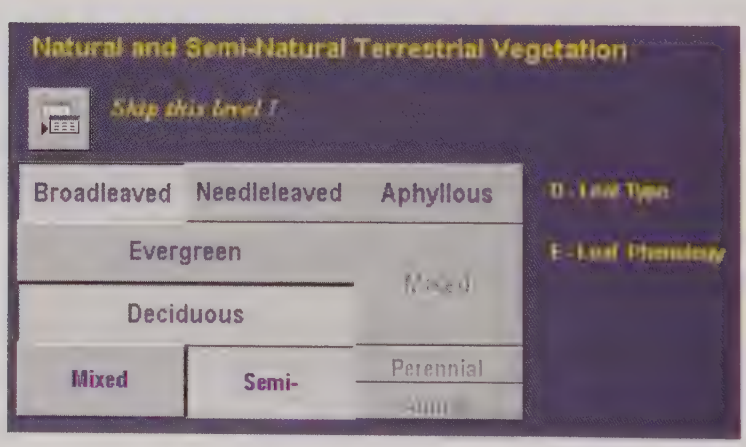
The pure land cover classifiers are always presented in blocks in which the choices are mutually exclusive, i.e., the user can select only one option. Even where there are two different levels, a more general level and a more specific level, presented in two rows (e.g., in *Life Form* "Woody" above "Trees" and "Shrubs" in Figure 14) only one option can be selected. If the user clicks on the button "Woody" followed by clicking on "Trees", the button "Woody" will return to its original, inactive, position.

FIGURE 14.
Example of classifier options at different levels of detail (major land cover type A12 - classifier *Life Form* with a first general level and a second more detailed level).



There are also options that further modify a classifier option (Figure 15). These are called Modifiers and they immediately follow a classifier option (e.g., in Leaf Phenology for Forbs and Graminoids; "Mixed" above "Perennial" and "Annual;" or in Height for all *Life Forms*). Modifiers belonging to one classifier option are mutually exclusive. Only after selection of the classifier can a modifier be added. If the user clicks the button of a modifier without having clicked on the appropriate classifier first, a message will pop up to inform the user that the classifier should be selected first.

FIGURE 15.
Example of modifier that further defines a classifier option (major land cover class A12 - classifier *Leaf Phenology* with modifier options *Mixed* and *Semi-Deciduous*).

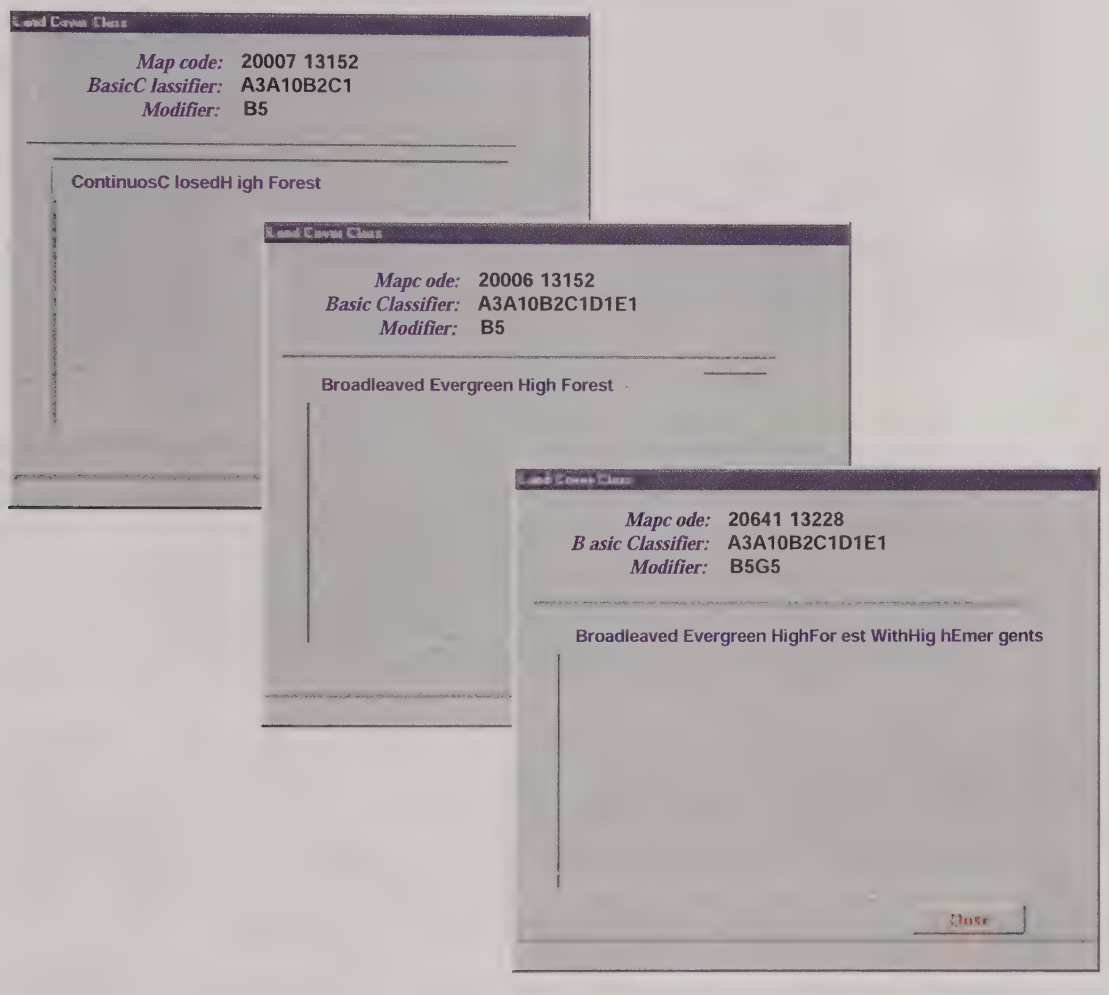


The use of these modifiers will generate (examples are shown in Figure 16):

- a separate Boolean Code (e.g., "Basic Classifier: A3A10B2C1" and "**Modifier: B5**")
- a distinct numerical code which follows the classifier code and is separated from it by a hyphen (e.g., 20007-**13152**); and
- a change to the standard name (e.g., Continuous Closed **High** Forest).

The more levels with their classifiers that are used, the more specific becomes the land cover class defined. Choices made at a high level may have implications for the availability of a certain classifier at a lower level. If certain options are no longer valid the buttons are disabled. In this way the user is guided through the program and invalid choices prevented.

FIGURE 16.
Examples of *Show Class* windows with a land cover class defined in the *Natural and Semi-Natural Terrestrial Vegetation* major land cover type.



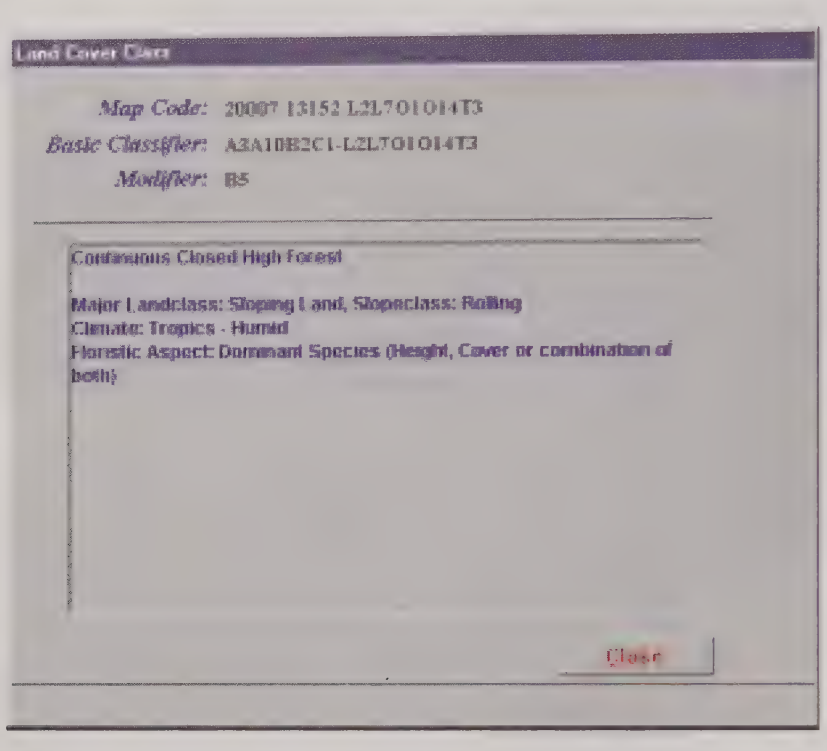
Environmental Attributes

The environmental attributes are not hierarchically ordered and the user is free to add appropriate choices in any order. Use of these attributes further defines the environmental settings in which a land cover unit is found (Figure 17). The options within one environmental attribute are mutually exclusive. Use of attributes will result in:

- a separate string of codes in the Boolean formula (e.g., Basic Classifier: A3A10B2C1-L2L7, Modifier: B5);
- no alteration of the numerical code (e.g., 20007-13152 remains unchanged); and

- no change in the standard name, as these choices follow the standard name and each choice refers back to the attribute itself (e.g., Class Name: Continuous Closed High Forest; **Major Landform: Sloping Land**; **Slopeclass: Rolling**).

FIGURE 17.
Example of *Show Class* window with a land cover class with additional environmental attributes: Landform and Climate.


Land Cover Class
Map Code: 20007 13152 L2L7T1O14T3
Basic Classifier: A3A10B2C1-L2L7T1O14T3
Modifier: B5
Continuous Closed High Forest
Major Landclass: Sloping Land, Slopeclass: Rolling
Climate: Tropics - Humid
Floristic Aspect: Dominant Species (Height, Cover or combination of both)
Close

Specific Technical Attribute

Use of the specific technical attribute will further define the land cover class using the related discipline (e.g., for vegetation, the method of how species were recorded can be specified; for cultivated areas, the crop type can be specified) (Figure 18). Again choices are mutually exclusive. Use of a specific technical attribute will result in:

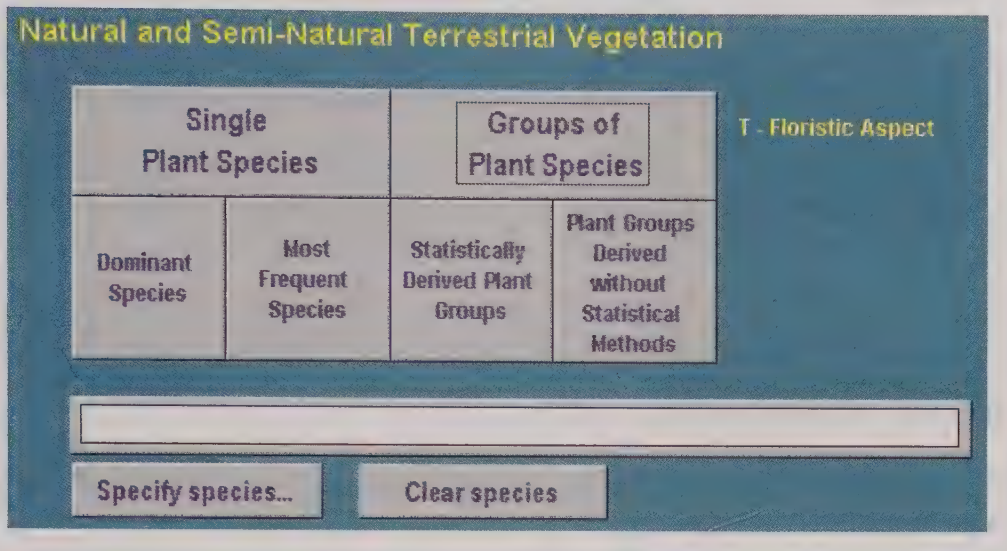
- a separate code added to the string of codes of attributes in the Boolean formula (e.g., Basic Classifier: A3A10B2C1-L2L7**T3**, Modifier: B5);

- no alteration of the numerical code (e.g., 20007-13152 remains unchanged);

- no change in the standard name as the specific technical attribute choice follows the standard name and after any environmental attributes used (e.g., Class Name: Closed High Forest; Major Landform: Sloping Land; Slopeclass: Rolling; **Floristic aspect: Dominant species (Height or cover or a combination of both)**).

The user can go through the levels of the Modular-Hierarchical Phase of certain major land cover classes and build up as many classes as needed. These classes can be stored in the Legend Module, described in detail in the next Section.

FIGURE 18.
Example of the use of the Specific Technical Attribute *Floristic Aspect*.



5.2 LEGEND

5.2.1 Purpose

The main purpose of the Legend Module is to store the land cover classes identified in a hierarchical structure that groups the classes according to the main land cover type. Therefore the Legend usually contains only a subset of the Classification, that is those classes which are applicable in the area (to be) interpreted or mapped.

In addition to providing a hierarchical structure, the Legend also offers capabilities to display, edit and add user-defined attributes to a land cover class. It provides standard descriptions for the classes identified and the classifiers used, and all this information can be exported in various formats.

Because in the Legend the classification is applied to a specific area, *Mixed Mapping Units* can be formed. A Mixed Mapping Unit can comprise two or three classes from the same major land cover type, or two or three classes from different major land cover types. The order of the classes in a Mixed Mapping Unit reflects the dominance in the mapping unit (see also Section 2.5).

5.2.2 How To Create A Legend?

Land cover classes are defined in the Classification Module. A Legend is created by storing these land cover classes in the Legend. To store a class defined in the Classification Module, the "Write Class to Legend" button needs to be clicked on in the Actions Panel of the Classification Module (see Section 4.1), upon which a sub-menu is shown (Figure 19). This sub-menu questions the user whether the class is a "*Single or Mixed Unit?*" The following choices are available: either

- clicking on the *Single* option stores the class defined in the Legend and the user can define the next new land cover class; or

- clicking on the *Mixed* option makes the program keep the first class defined in memory and await definition of the second and/or third component of the Mixed Mapping Unit.

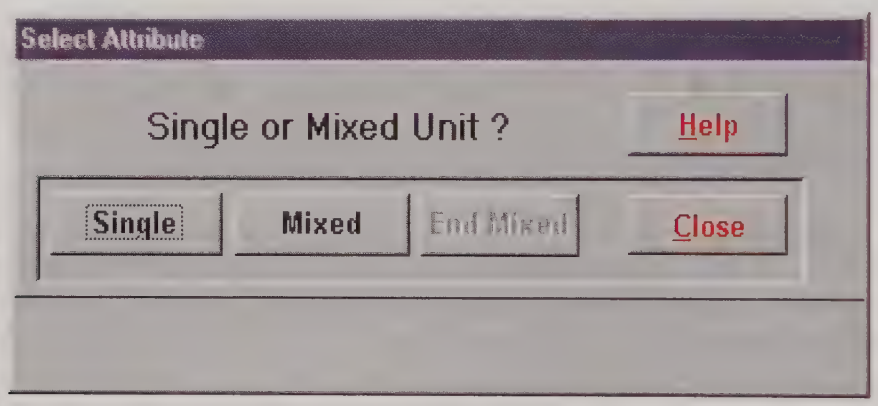
- If the second land cover class is the ultimate component of the Mixed Mapping Unit, the user should then click on *End Mixed*, but if there is a third component the user should click on *2nd Mixed*.

- To define a third, and final, component of a Mixed Mapping Unit, the third land cover class needs to be defined, followed by clicking on *End Mixed*.

- To annul storage of a land cover class in the Legend the user can select *Cancel*, or, if the second or third component defined should not be written to Legend, the same button can be used. However, by annulling this component, the system still expects definition of the second and/or third elements.

The *Help* button gives further information on which option to select in case of writing a class to the Legend.

FIGURE 19.
From the Classification Module to Legend: window in which the user has to select whether or not the defined land cover class is part of a *Mixed Unit*.



In the current classification (and its derived Legend) a *Mixed Unit* is defined as a **mapping unit where more than 25 percent of the dominant cover belongs to another land cover class**. The dominant land cover class is always the first class mentioned (e.g., Closed Forest/Herbaceous Fields indicates a Mixed Mapping Unit of forest and fields where the forest is the class covering the bigger portion of terrain (more than 50 percent), while the agricultural fields cover at least 25 percent of the area, but less than 50 percent).

The Mixed Mapping Unit is then stored in the Legend. The user can continue to define other land cover classes or switch to any of the other program modules.

There are two ways to enter the Legend Module, either:

- directly from the *Main Menu*; or

- from the appropriate button of the Actions Panel in the *Classification Module*.

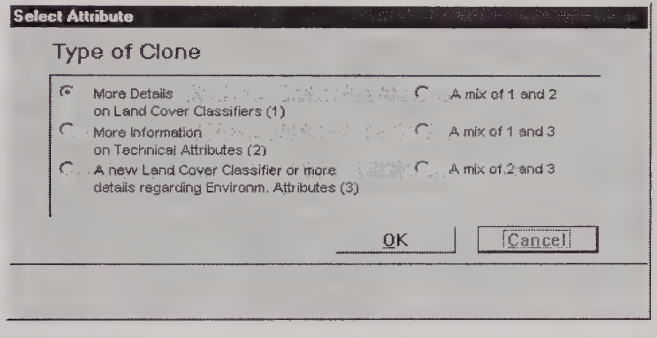
In the Main Menu there is a button which leads the user directly to the Legend Module. However, if no land cover classes have been defined in the Classification Module and subsequently stored in the Legend, the Legend will be empty.

From the Classification Module there is a special button to go direct to the main Legend menu, from where the various options can be chosen, as explained below.

5.2.3 Adding User-Defined Attributes

Land cover classes can be "cloned" in order to add some specific user-defined attributes to the standard land cover class selected. This allows the addition of more specific and user-oriented attributes while maintaining a standardized land cover class. The user may want to further define a classifier and/or attribute already used, or the user might want to add a new attribute. A standard set of options is provided (see Figure 20).

FIGURE 20.
Window with the options for definition of the *Type of Clone* in order to add a User-Defined Attribute.


Select Attribute
Type of Clone
More Details on Land Cover Classifiers (1)
More Information on Technical Attributes (2)
A new Land Cover Classifier or more details regarding Environm. Attributes (3)
A mix of 1 and 2
A mix of 1 and 3
A mix of 2 and 3
OK
Cancel

In order to clone a standard land cover class and add a user-defined attribute, follow the steps below (an example is shown in Figure 21):

(1) Identify the land cover class to be cloned in the *Identify class to be cloned* box.

(2) Click on the button *Select.*

(3) A window opens with *Type of Clone,* in which one option needs to be selected, followed by clicking either *OK* to accept or *Cancel* if the operation needs to be cancelled. The option selected will add a figure between brackets to the coded string of classifiers of the class (e.g., 20007-13152(3)).

(4) The cloned land cover class is shown in the lower part of the screen.

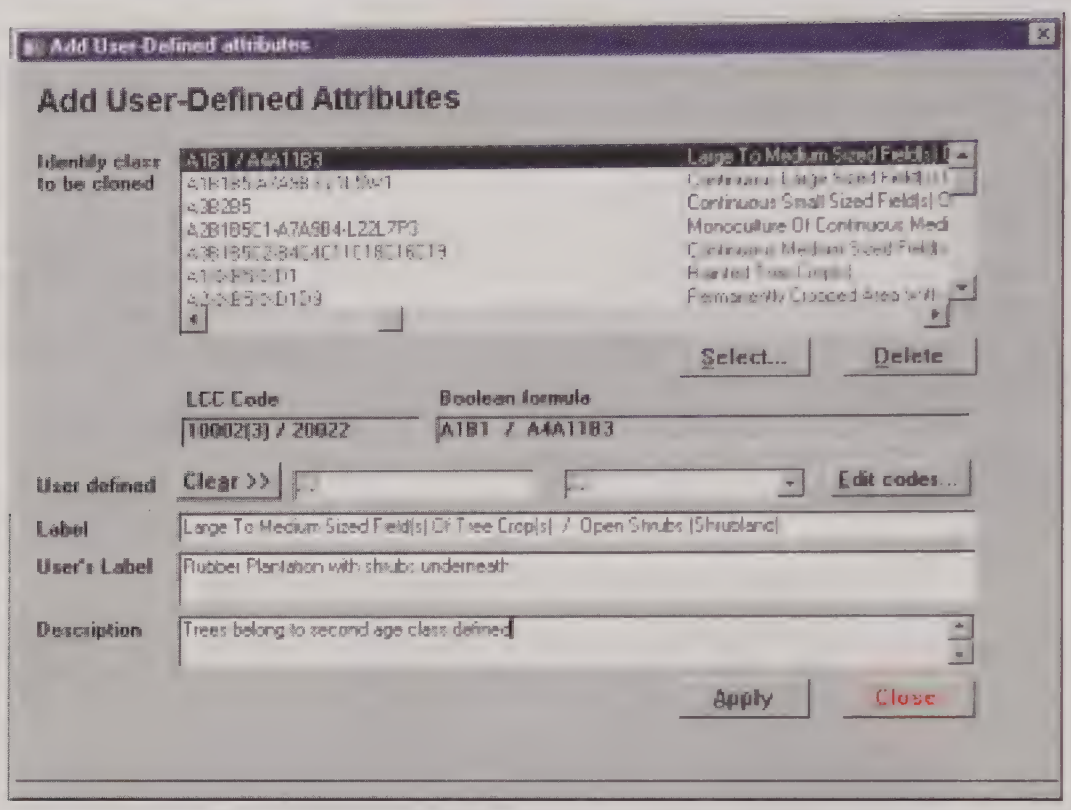
(5) Type the attribute to be added in the *User's Label* box and a description in the *Description* box, if any.

(6) Press *Apply.*

(7) A pop-up message with *Cloned legend successfully recorded* will be displayed. Press *OK.*

(8) Press *Close* when no more classes need to be cloned in order to add user-defined attributes.

FIGURE 21.
Example of Legend *User-Defined Attribute* within a mixed class.



5.2.4 Display

In Display, the classes contained in the Legend will be displayed in a pre-defined hierarchical structure (Figure 22):

(1) The land cover classes defined are grouped under the main land cover type they belong to, and according to the *Structural Domain* within one major land cover type (e.g., *Natural and Semi-Natural Terrestrial Vegetation* with the structural domains *Forest, Woodland, Thicket, Shrubland, Grasslands* and *Lichens/Mosses.*) (Box 2 and Appendix B).

(2) Within one domain, classes are hierarchically ordered according to the level of classifiers used.

(3) Three items are displayed vertically in the same column: (1) the numerical code, the *Map Code*, of the land cover class; (2) the string of *classifiers* used; and (3) the *Land Cover Class* name.

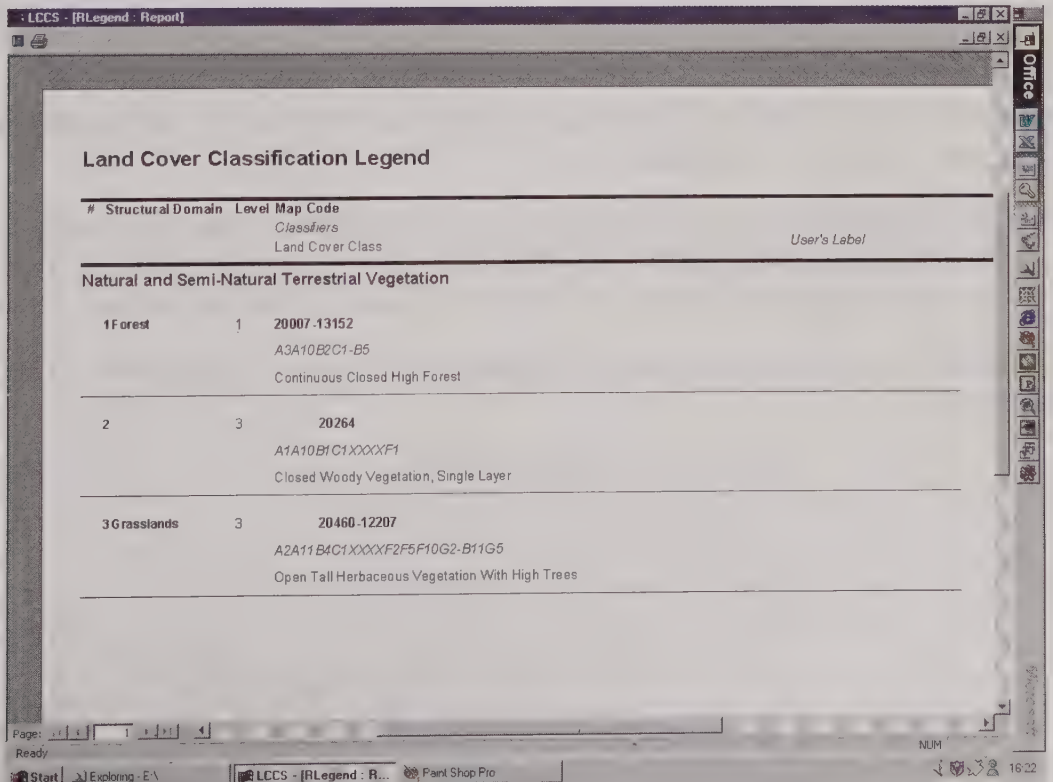
(4) The column *User's Label* will be displayed as an empty column unless a label has been added by the user in the Legend – Edit function.

Mixed Mapping Units will be displayed under the Structural Domain *Mixed Class* under the major land cover type of the first, and therefore dominant, element of the class.

FIGURE 22.
Example of Legend *Display*.

BOX 2. **MAJOR LAND COVER TYPE WITH THEIR STRUCTURAL DOMAINS**

A11. Cultivated and Managed Terrestrial Areas	Tree Crops Shrub Crops Herbaceous Crops Graminoid Crops Non-Graminoid Crops Managed Lands
A12. Natural and Semi-Natural Terrestrial Vegetation	Forest Woodland Thicket Shrubland Grasslands Sparse Vegetation Lichens/Mosses
A23. Cultivated Aquatic or Regularly Flooded Areas	Aquatic Or Regularly Flooded Graminoid Crops Aquatic Or Regularly Flooded Non-Graminoid Crops
A24. Natural and Semi-Natural Aquatic or Regularly Flooded Vegetation	Forest Woodland Closed Shrubs Open Shrubs Grasslands Sparse Vegetation Lichens/Mosses
B15. Artificial Surfaces and Associated Areas	Built-Up Areas Non Built-Up Areas
B16. Bare Areas	Consolidated Areas Unconsolidated Areas
B27. Artificial Surfaces and Associated Areas	Artificial Waterbodies Artificial Snow Artificial Ice
B28. Natural Waterbodies, Snow and Ice	Natural Waterbodies Snow Ice



5.2.5 Edit

In Edit, the classes comprising the Legend are displayed, placing the elements composing the class in different boxes.

The numerical code and standard name cannot be edited. These are standard elements of a class and are identical for anyone in the world using the system and defining the same class. These elements help the user to trace which class needs to be edited.

The *User's Label* and *Description* are the two boxes in which the user can enter user-defined labels and descriptions. These will be displayed in the *Legend – Display* once entered.

Two buttons are displayed at the bottom of the screen:

- *Delete* to delete a complete land cover class from the Legend; and
- *Close*, use of which stores the new User's Label(s) and/or Description(s) in the Legend and returns the user to the main Legend menu. The *Legend – Display* option can be used to check that the operation has been implemented satisfactorily.

5.2.6 Standard Description

The user is provided with a *Standard Description* for every class defined in the Classification Module and stored in the Legend. This description gives more insight into the classifiers used and the structure of the class than can be inferred from the standard name alone. User-defined attributes are not incorporated in the Standard Description; for an explanation of those, the *Legend – Edit* option should be used.

In the Standard Class Description, classes are hierarchically arranged according to the Structural Domains of each Major Land Cover Type (see Box 2), identical to the Legend Display, and the following information is shown:

(1) The major land cover type with its hierarchically ordered *Structural Domains* followed by the *Land Cover Class Code* (*LCC Code*) and Boolean formula or Map Code (*LCC Formula*).

(2) The standard land cover class name (*LCC Label*) followed by the user-defined label, if any (*LCC User-defined label*).

(3) The Standard Description (*Standard Description*) of the class followed by the *User-defined description*, if any. This description may be useful in reports accompanying maps in which the classes of the map are described in more detail.

The Standard Description can be printed by selecting *Print* from the toolbar at the top of the screen (Figure 23).

FIGURE 23.
Example of the Legend *Standard Description*.5.2.7 Classifiers Used

Land Cover Classification - Standard Description *27-Sep-00*

# Structural domains LCC Code LCC Formula	LCC label *LCC User defined label*	Standard Description *User defined description*
Cultivated and Managed Terrestrial Area(s)		
1 Herbaceous Crops		
10028	Continuous Large To Medium Sized Field(s) Of Herbaceous Crop(s)	Continuous large-to-medium-sized field(s) are covered by herbaceous crops. The field size can be subdivided optionally into large or medium.
A3B1B5		

In the *Display, Edit, Add User-Defined Attribute* and *Standard Description* menu options, the Boolean Formula of the land cover class defined is displayed. The menu option *Classifiers Used* gives the user the possibility to interpret what these code strings mean, as it presents, under the headings of the major land cover types, the key to the codes used in the Legend (Figure 24).

This explanation will be useful in GIS/database queries where the user wants to re-select the data according to a certain classifier or a group of classifiers. Combining numerical codes and the Boolean formulae allows re-grouping according to user-defined queries.

5.2.8 Print

Clicking on this menu option will not invoke a new screen display but will send the created Legend to the printer. The output appears as described under *Display* (Section 5.2.3).

5.2.9 Save/Retrieve

This set of options allows the user to Save and Retrieve the legends created and is without exchange facility with other LCCS users. A legend stored in this way can only be retrieved by the same copy of the software application.

- To *Save* a Legend: click on Save and a window will open in which the user is asked to type the legend name in the appropriate box. No pathway needs to be entered.

FIGURE 24.
Example of Legend *Classifiers Used.*

Land Cover Classification Legend

List of Land Cover Classifiers Used

#	Classifier	Classifier Label
Cultivated and Managed Terrestrial Area(s)		
1	A3	Herbaceous Crops
2	B1	Large To Medium Sized Field(s)
3	B5	Continuous
Natural and Semi-Natural Terrestrial Vegetation		
4	A1	Woody Vegetation
5	A10	Closed > (70-60)%
6	A11	Open (70-60) - (20-10)%
7	A2	Herbaceous Vegetation
8	A3	Trees
9	B1	(7 - 2m)
10	B11	Tall
11	B2	(> 30 - 3m)
12	B4	(3 - 0.03m)
13	B5	High
14	C1	Continuous
15	F1	Single Layer

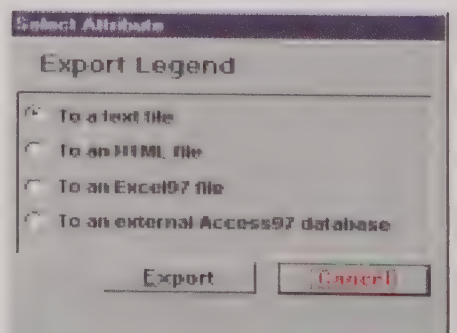
- To *Retrieve* a Legend: click on Retrieve and a window will open containing the names of the legends already saved. Click with the mouse on the correct name and click *OK* or *Cancel.*

- The option *Delete* will delete a stored legend.

5.2.10 Export/Import

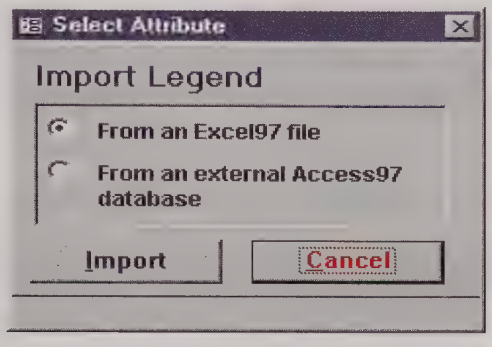
Clicking on this menu option will invoke a new screen display offering with four choices. This set of options allows storage of legends in specified formats and allows exchange of legends with other LCCS users on different computer platforms.

- To *Export a Legend:* click on *Export* and select one of the four options displayed, namely:



The text file will store the Legend as a .TXT file; the HTML file as an .HTM file; the spreadsheet option as an .XLS file; and the external Access database for re-import as an .MDB file.

- select *Export* to export the legend in the selected file format(s).
- a new window is opened in which the user can type the name and select the directory in which to store the legend.



- To *Import a Legend:* click on *Import* and specify whether it is a spreadsheet or an external database file and type the pathname and filename of the legend to be imported.

5.2.11 New Legend

This menu's options removes the existing Legend, which can be stored in the *Output to* window specifying the directory and name. The default name is *TLegend.txt* and a new Legend can be created as the user is so informed.

5.2.12 Close

This menu option will return the user to the where the user was previously. If the user was in the Classification Module before, new classes can be defined and written to the Legend.

5.3 FIELD DATA

5.3.1 Purpose

In this module, which will become available in version 2.0, the sample site is described and other relevant information can be stored. These data are automatically classified by being translated into the classifiers, modifiers and attributes of LCCS. The sample site can be described using a minimum dataset, a user-defined set or a full set of items. The minimum data set contains only those items needed to meet the requirement to be able to classify the entry according to the Classification System. If the user-defined or customized option is selected, the user needs to choose from the menu which items will be described. These settings can be saved in a file. It will depend on the objectives of a field survey as to which option will be chosen.

The Field Data Module is designed in such a way that the user does not need to be familiar with the classification concepts. Based on the information observed, the Module will check the various concepts in order to define, for instance, the layering in a vegetation type or the type of cover present.

5.4 TRANSLATOR

5.4.1 Purpose

Existing classifications and legends can be translated into the reference classification. By translating them into the Land Cover Classification System, this system acts as a reference base in which correlation between classifications and/or legends becomes possible.

The Translator Module offers the possibility to:

- translate classes of existing classifications and legends into LCCS;
- assess similarity of classes according to other classifications and legends using LCCS as a reference base;
- compare classes of translated classifications and legends and their attributes, using LCCS as a reference base, at the level of the individual classifiers used; and
- to compare two land cover classes of LCCS and their attributes (these may be two classes belonging to the same major land cover type or two classes belonging to two different land cover types), which may be useful when comparing a preliminary land cover class with a validated land cover class in field surveys.

FAO will coordinate input of translated classifications and legends for the time being. Major current classifications translated into the system will come as standard with the software application or will be provided at a later date.

From the Main Menu the user can go directly to the Field Data Module. This provides a short cut in the event that preliminary classes need to be compared with final classes derived through field observation.

In the Menu, the user will also find an option to return to the Main Menu.

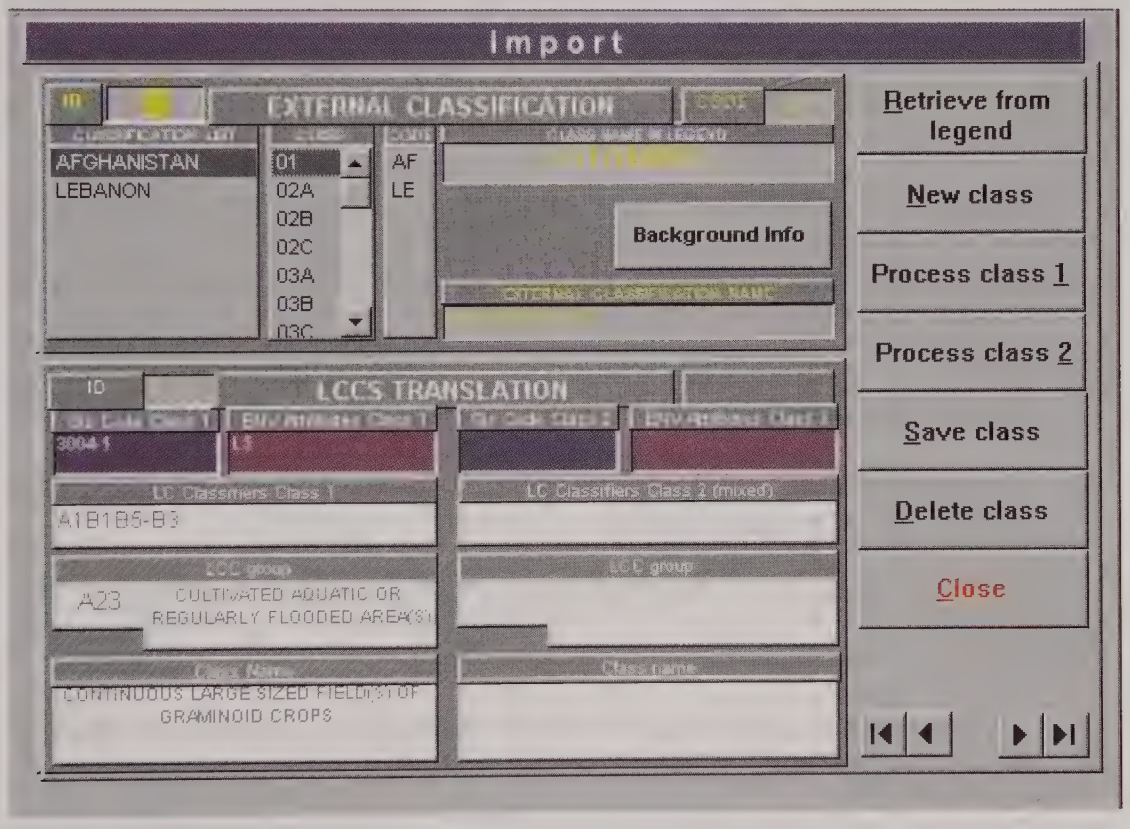
5.4.2 How to translate a classification or legend

Translation of external classifications and legends into LCCS can be done by using the Classification Module and thus creating a Legend (see Sections 5.1 and 5.2) which can be imported in the Translator Module, or by direct input of external classes. In both cases the *Import* option will be used.

Import

If the user has created a Legend containing all the classes of the classification or legend to be imported, these classes can be imported in the Translator Module one by one. In the menu of the Import screen (Figure 25), the option *Retrieve From Legend* should be selected, which displays the screen in which classes from the legend can be imported.

FIGURE 25.
First screen of *Import*.



The *Retrieve From Legend* option will open the *Legend Export to Translator* window. In the box the classes stored in the Legend Module are displayed. How to export a class from the Legend Module into the Translator Module is described below:

(1) Identify the land cover class to be exported to the Translator Module (or Imported into the Translator Module).

(2) Click on *Select as 1st* to display the class in the *Classes Identified* Frame.

(3) Add the user-defined elements from the original external legend to the land cover class selected, i.e., add a numerical ID, type the original name in the box *Class Name in Legend*, type the external legend or classification name in the box *Ext. Classification Name*.

(4) Select *Export.*

(5) This will bring the user back to the Import window.

(6) Select *Process Class 1* to let the system find the corresponding information in the LCCS databases and type an ID in the box above *GIS Code Class1.*

(7) Select *Save Class* to store the class.

(8) Repeat for other classes.

If a class consists of two LCCS classes, i.e., a Mixed Class, the procedure is slightly different. The *Select as 2nd* option should be used immediately after having selected the first class of the mixed unit (Step 2 above). After having completed steps 3 to 6, the option *Process Class 2* should be selected, followed by Steps 7 and 8. The components of a Mixed Class have to be defined as single classes in order to recompose the mixed class in the Translator – Import.

This stepwise procedure allows each individual land cover class in the Legend to be exported into the Translator Module.

The second option is to add the classes, one by one, into the Translator Module using the Import screen display and without using the *Retrieve from Legend* option (Figure 26). A new and unique legend name needs to be added to the existing list and for each class to be imported the user needs to follow the sequence below:

(1) Type a unique ID in the *ID* box; this can be the code in the original external legend or classification.

(2) Type a unique two-letter code to identify this legend or classification (e.g., AF is typed for the Afghanistan Land Cover Legend).

(3) Type the original name in the *Class Name in Legend* box (e.g., Afghanistan).

(4) Type *Background Information* in the appropriate box.

(5) Type a unique sequential numerical ID for the land cover class in the *ID* box of the LCCS Translator.

(6) Type the *GIS Code Class 1* (derived from the Classification Module).

(7) Type the codes of the Environmental Attributes (derived from the Classification Module), if any.

(8) Select *Process Class 1*, the system will now find in the databases the corresponding class name.

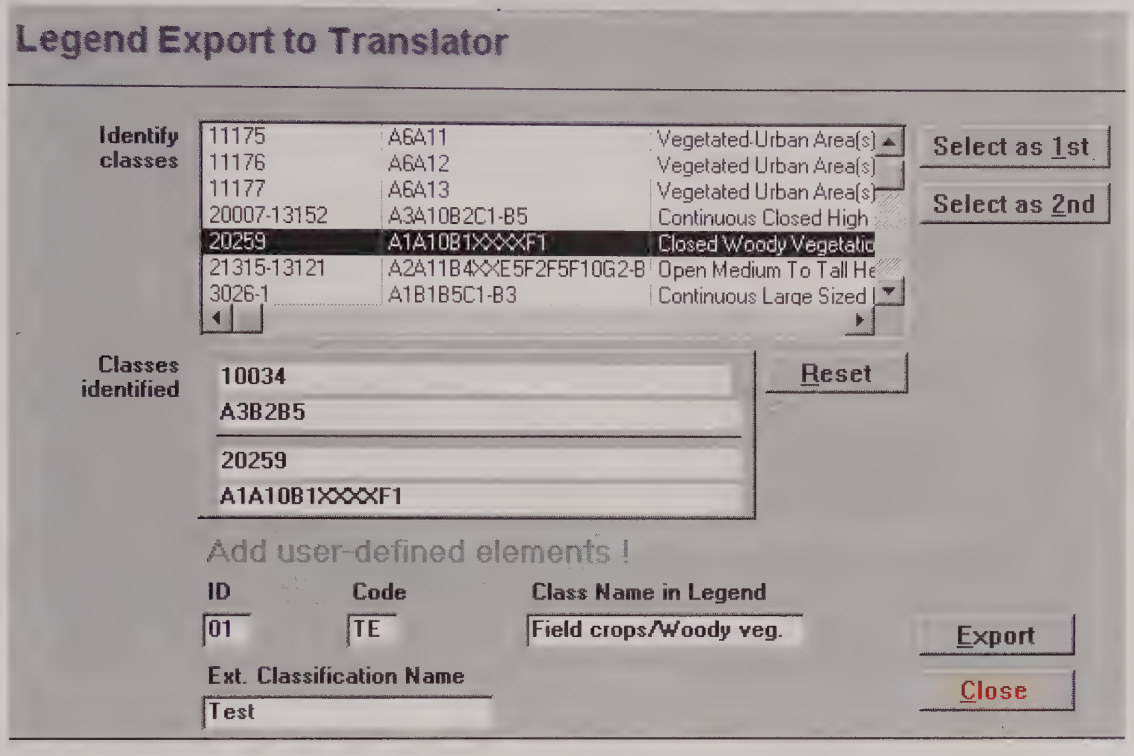
(9) Reiterate Steps 6 to 8 if there is a second component of the class, using the second set of boxes and click on *Process Class 2* to finish.

(10) Click on *Save* when the boxes are filled with the appropriate labels of LCCS.

(11) Click on *New Class* to import a new land cover class.

This sequence needs to be completed for any class of the external legend to be imported. By clicking on *Close* the user returns to the Main Menu of the Translator Module.

FIGURE 26.
Retrieving individual land cover classes from the Legend Module into the Translator - *Import* facility.



Display Imported Legend

This screen will display the final result of the imported external classification and its translation into LCCS. The user can choose to display according to the order in the original classification or legend, or to display according to the order of LCCS. *Mixed Classes* will be displayed according to the dominant, and first mentioned, class.

To display an imported Legend, follow these steps:

(1) Select the classification and press the *Go Next* button (button with arrow pointing to the right).

(2) The imported classes will be shown in the order of the original IDs on the left side of the screen.

(3) The *Show LCCS Legend* will display the translation into LCCS classes.

(4) There are two other options for displays which affect the order in which the classes are displayed: *Original A–Z* follows the order of the imported legend or classification, whereas *LCCS A–Z* follows the intrinsic LCCS order.

(5) The *User-defined Legend Option* will write selected classes to a file.

(6) The *Close* option will bring the user back to the Main Menu of the Translator Module.

5.4.3 Comparison of External Classes

Similarity Assessment

The similarity of individual external classes to other legends or classifications can be quantified. Select the option *Similarity Assessment* in the Main Menu. In the screen display the user has to select the reference class with which the other classes will be compared. A number of threshold settings are provided. These values are stored in a table of correspondence in which the following assumptions have been made (see Appendix D):

- the classifier *Trees* is the same whether coming from Natural or Semi-Natural Vegetation or from Cultivated Areas; and
- the classifier *Herbaceous* comprises Graminoids and Forbs, or Non-Graminoids, therefore the threshold has been set at 50 percent. The same applies to Woody.

To make a *Similarity Assessment* of two classes (an example is shown in Figure 27):

(1) Select the *Classification Name* of the legend that should provide the Reference Class.

(2) Select *Classes* and highlight the appropriate class.

(3) Click the Reference Class set of arrows to get the selected class in the Reference Class box.

(4) Click the *Compare* button.

(5) Click on the *Reference Class* button and the class selected will be shown on the left side, together with its classifier and the options used.

(6) Select *Empty Report* and press *OK*.

(7) Select the legend or classification to be compared.

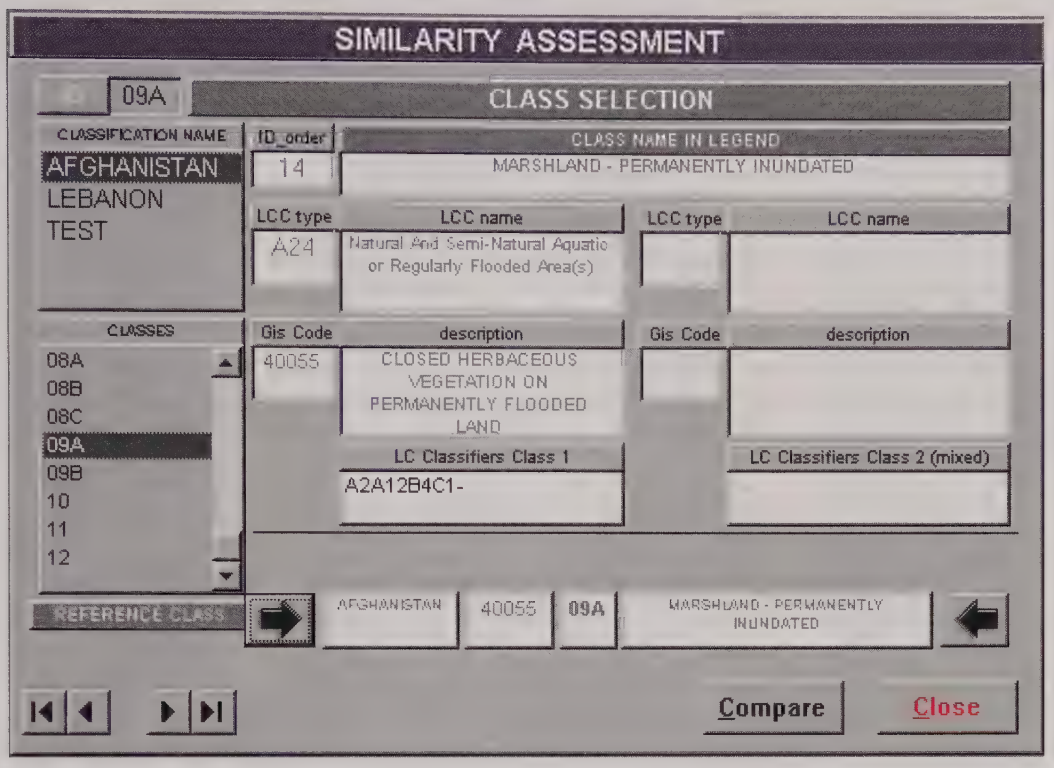
(8) Set the threshold values. Two groups are distinguished: (1) to set if the first classifier should be the same; (2) to set the threshold value of the similarity.

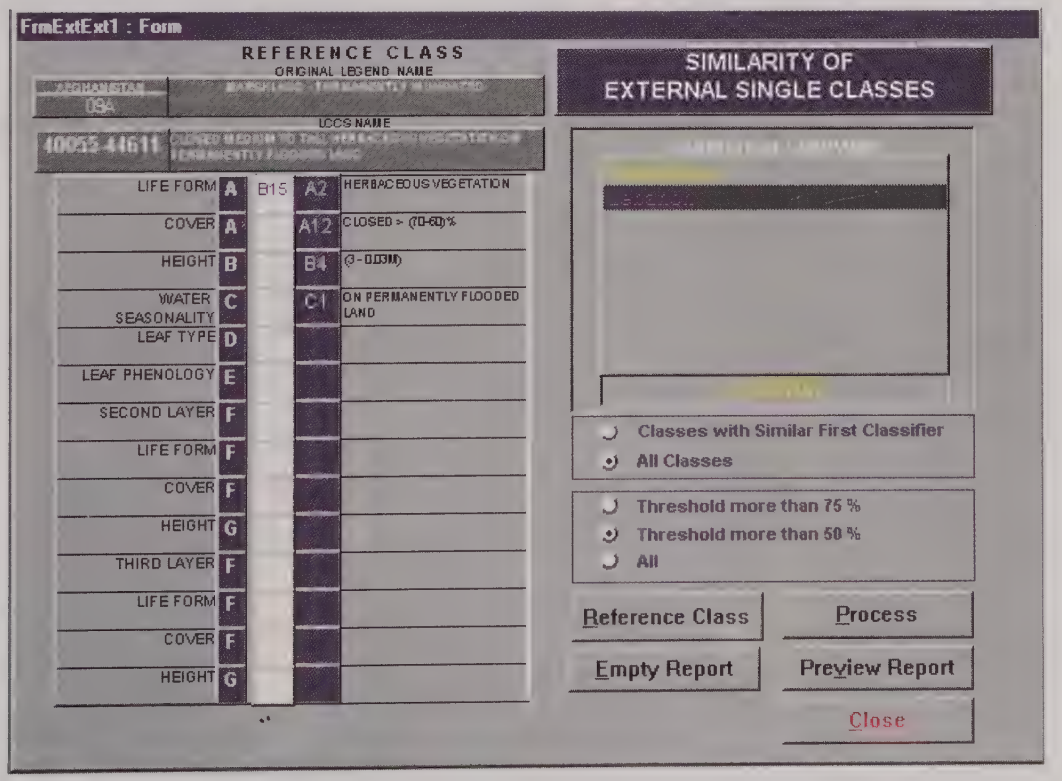
(9) Click *Process* and the assessment will start. A pop-up message will be displayed when the assessment is completed.

(10) Select *Preview Report* and a report will be shown showing the Reference Class, the legend or classification selected for similarity assessment and the results, namely the classes and the similarity value.

(11) Select *Close* to return to the Main Menu of the Translator Module.

FIGURE 27.
First screen of the *Similarity Assessment*, in which the reference land cover class is selected and second screen in which a number of options need to be selected.





Comparison of External Classes

Once classes have been translated into LCCS, the system can act as a reference base for comparison. Individual classes can be compared at the level of their classifiers and attributes, though only those which are provided by the system; user-defined attributes will not be considered. By selecting the option *Comparison of External Classes* from the Main Menu, a screen will be displayed showing the translated classification available or legends and their class codes. By selecting a classification by clicking, and a class by clicking, the boxes with Class 1 and Class 2, if appropriate, will be filled. The arrows allow the user to select either of the two classes as the reference class. Selection of a second class of the same classification or legend, or a different one, followed by putting the selected class in the right box of class to be compared allows the user to go on to the next screen where the actual comparison will take place. Clicking on the button *OK* will bring the user to the comparison screen. Click on *Display* and it will show the two classes and their classifiers; clicking on the button *Compare* will activate the comparison. The comparison will take into account all the classifiers of the class to be compared with those of the reference class. The following colours may be displayed:

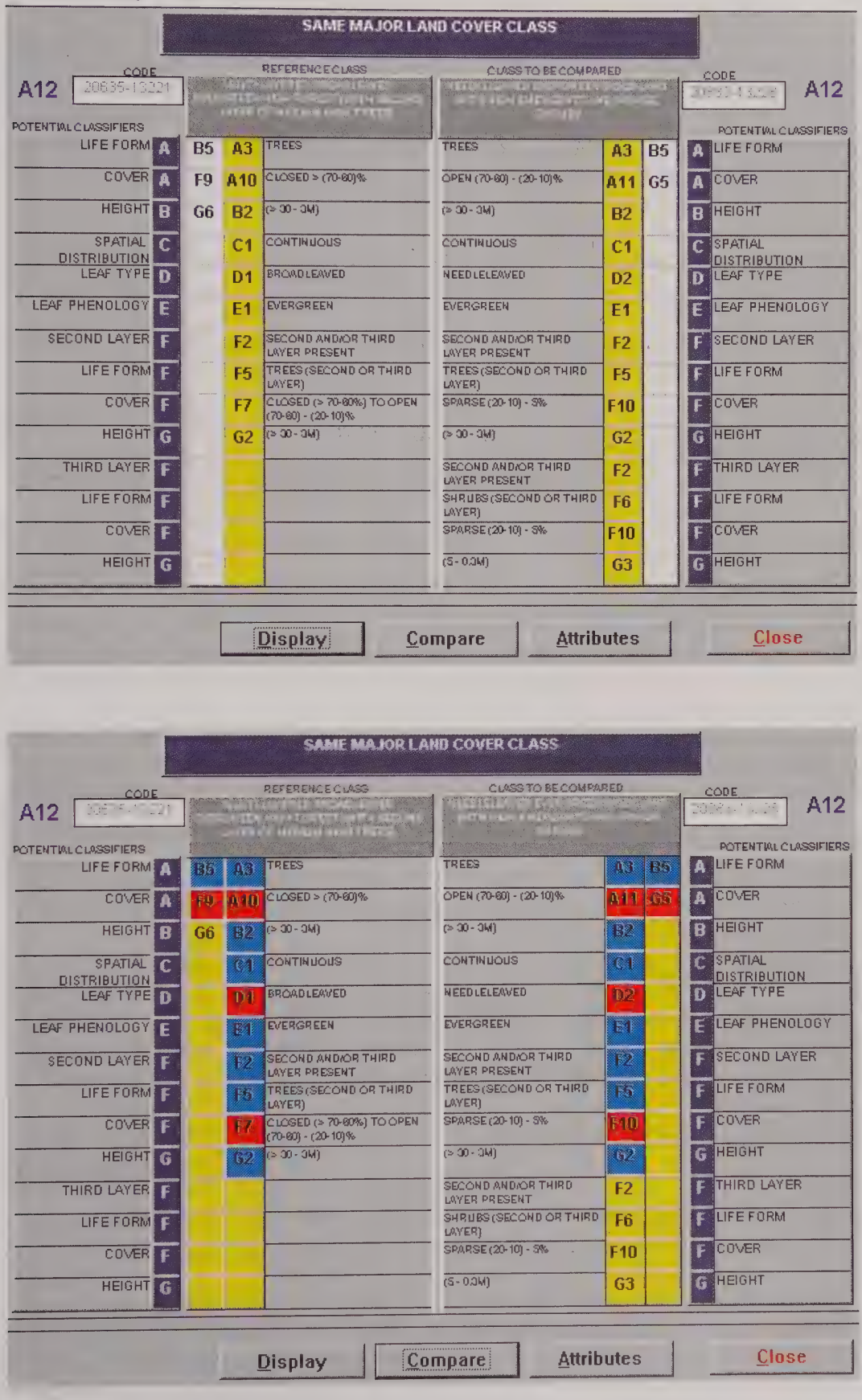
- blue: from the same classifier, the options selected are identical.
- red: from the same classifier, different options have been selected (e.g., from the classifier *Life Form* one class contains the option *Trees* and the other *Non-Graminoids*).
- Yellow: the classifiers are different and comparison does not make sense, or only one of the two classes contains this classifier.

The same procedure can be followed for comparison of Environmental Attributes, if any, by selecting the *Env. Attributes* option.

5.4.4 Comparison of two LCCS classes

Two classes of LCCS may be compared to one another at the level of the classifiers and attributes used. Such a comparison may be based on a class defined in a preliminary interpretation and the other one derived from field observation. By selecting *Comparison of Two LCCS Classes* from the Main Menu a screen is invoked in which the Class codes of the two classes to be compared should be typed, or the most recent data entry of the Field Data Module is displayed and the user has to fill the box with the class to be compared. The *Reference Class* and *Class To Be Compared* can also be entered manually by typing the correct codes in the appropriate boxes. The same set of screens will thereafter be displayed as described under *Comparison of Two External Classes* (Section 5.4.3). Figure 28 shows an example of two external classes being compared.

FIGURE 28.
Comparison of two external classes using LCCS as reference classification system.


SAME MAJOR LAND COVER CLASS
CODE
A12
REFERENCE CLASS
CLASS TO BE COMPARED
CODE
A12
POTENTIAL CLASSIFIERS
LIFE FORM A B5 A3 TREES TREES A3 B5 A LIFE FORM
COVER A F9 A10 CLOSED > (70-80)% OPEN (70-80) - (20-10)% A11 G5 A COVER
HEIGHT B G6 B2 (> 30 - 3M) (> 30 - 3M) B2 B HEIGHT
SPATIAL DISTRIBUTION C C1 CONTINUOUS CONTINUOUS C1 C SPATIAL DISTRIBUTION
LEAF TYPE D D1 BROAD LEAVED NEED LELEAVED D2 D LEAF TYPE
LEAF PHENOLOGY E E1 EVERGREEN EVERGREEN E1 E LEAF PHENOLOGY
SECOND LAYER F F2 SECOND AND/OR THIRD LAYER PRESENT SECOND AND/OR THIRD LAYER PRESENT F2 F SECOND LAYER
LIFE FORM F F5 TREES (SECOND OR THIRD LAYER) TREES (SECOND OR THIRD LAYER) F5 F LIFE FORM
COVER F F7 CLOSED (> 70-80%) TO OPEN (70-80) - (20-10)% SPARSE (20-10) - 5% F10 F COVER
HEIGHT G G2 (> 30 - 3M) (> 30 - 3M) G2 G HEIGHT
THIRD LAYER F SECOND AND/OR THIRD LAYER PRESENT F2 F THIRD LAYER
LIFE FORM F SHRUBS (SECOND OR THIRD LAYER) F6 F LIFE FORM
COVER F SPARSE (20-10) - 5% F10 F COVER
HEIGHT G (5 - 0.3M) G3 G HEIGHT
Display
Compare
Attributes
Close

SAME MAJOR LAND COVER CLASS
CODE
A12
REFERENCE CLASS
CLASS TO BE COMPARED
CODE
A12
POTENTIAL CLASSIFIERS
LIFE FORM A B5 A3 TREES TREES A3 B5 A LIFE FORM
COVER A F9 A10 CLOSED > (70-80)% OPEN (70-80) - (20-10)% A11 G5 A COVER
HEIGHT B G6 B2 (> 30 - 3M) (> 30 - 3M) B2 B HEIGHT
SPATIAL DISTRIBUTION C C1 CONTINUOUS CONTINUOUS C1 C SPATIAL DISTRIBUTION
LEAF TYPE D D1 BROAD LEAVED NEED LELEAVED D2 D LEAF TYPE
LEAF PHENOLOGY E E1 EVERGREEN EVERGREEN E1 E LEAF PHENOLOGY
SECOND LAYER F F2 SECOND AND/OR THIRD LAYER PRESENT SECOND AND/OR THIRD LAYER PRESENT F2 F SECOND LAYER
LIFE FORM F F5 TREES (SECOND OR THIRD LAYER) TREES (SECOND OR THIRD LAYER) F5 F LIFE FORM
COVER F F7 CLOSED (> 70-80%) TO OPEN (70-80) - (20-10)% SPARSE (20-10) - 5% F10 F COVER
HEIGHT G G2 (> 30 - 3M) (> 30 - 3M) G2 G HEIGHT
THIRD LAYER F SECOND AND/OR THIRD LAYER PRESENT F2 F THIRD LAYER
LIFE FORM F SHRUBS (SECOND OR THIRD LAYER) F6 F LIFE FORM
COVER F SPARSE (20-10) - 5% F10 F COVER
HEIGHT G (5 - 0.3M) G3 G HEIGHT
Display
Compare
Attributes
Close

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ACRONYMS AND ABBREVIATIONS

AGLS	Soil Resources, Management and Conservation Service (FAO)
DIS	Data and Information System (IGBP)
GIS	Geographical Information System
IGBP	International Geosphere-Biosphere Programme
LCCS	Land Cover Classification System
SDRN	Environment and Natural Resources Service (FAO)
USDA	United States Department of Agriculture

APPENDIX A.

GLOSSARY OF CLASSIFIERS, MODIFIERS AND ATTRIBUTES

NATURAL AND SEMI-NATURAL VEGETATED AREAS (A12 and A24)

A. LIFE FORM (A12 and A24)

A *Life Form* is a group of plants having certain morphological features in common (Kuechler and Zonneveld, 1988).

A further distinction is made between Lichens/Mosses and, according to the quality of the main axis or shoots, Woody or Herbaceous. For further subdivision, additional growth form criteria are: the quality of the main axis or shoots, subdividing Woody from Herbaceous; branching symmetry, subdividing Trees from Shrubs; and physiognomy of the herbaceous plants, subdividing Forbs and Graminoids from Lichens/Mosses (Strasburger *et al.*, 1983; Kuechler and Zonneveld, 1988).

Guidelines

The Life Form *is the first classifier the user will use and therefore the most critical one. Depending on the main* Life Form *selected, the classification and its software program will reduce the number of options available for the second and third strata.*

In selecting the main Life Form, *two main criteria have to be considered:*

- Definition of *Life Form*
- Definition of the dominance of a *Life Form*

***1. Definition of* Life Form**

Life Form *of a plant is defined by its physiognomic aspect. This is the case when* Woody *plants, subdivided into* Trees *and* Shrubs, *are distinguished from* Herbaceous *plants, subdivided into* Forbs *and* Graminoids, *and* Lichens/Mosses.

A condition of Height *is applied to separate* Trees *from* Shrubs*: woody plants higher than 5 m are classified as* Trees. *In contrast, woody plants lower than 5 m are classified as* Shrubs. *This general rule is subject to the following exception: a woody plant with a clear physiognomic aspect of trees can be classified as* Trees *even if the* Height *is lower than 5 m but more than 3 m. In this case, a subcondition of physiognomic aspect is added to the* Height *condition.*

These are the recommended thresholds for Life Form characterization, but exceptions are allowed:

- *Plants essentially herbaceous but with a woody appearance (e.g., bamboos and ferns) are classified as* Trees *if the height is more than 5 m, and as* Shrubs *if the height is less than 5 m.*
- *For the classifier* Woody *(indistinct and/or intricate mixture of trees and shrubs), the higher limit is set at 7 m and the lower one at 2 m.*

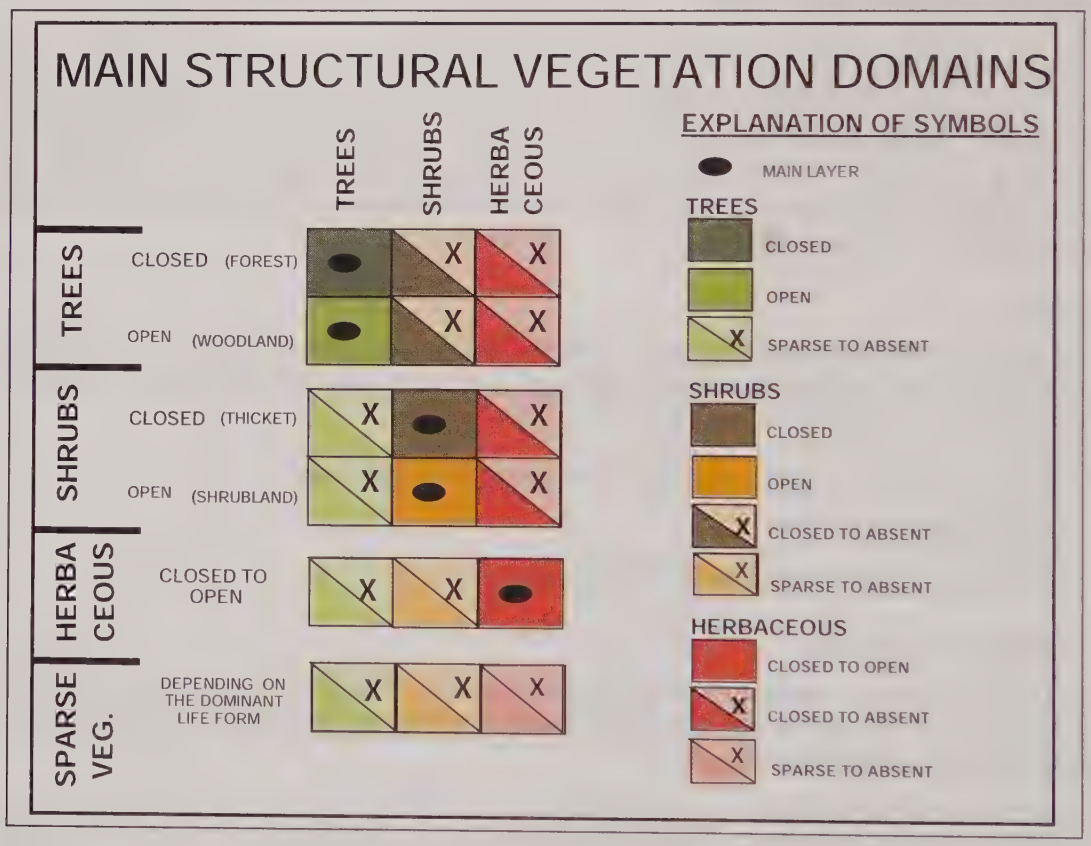
***2. Definition of the dominance of a* Life Form**

The dominance of the Life Form *is based on the "uppermost canopy" level, ranging from* Trees *to* Shrubs *to* Forbs/Graminoids. *This main condition for uppermost canopy has to be considered in conjunction with the sub-condition* Cover, *ranging from* Closed *or* Open *to* Sparse. *In other words, the uppermost canopy concept is only valid if the dominant* Life Form *has a cover either* Closed *or* Open. *If the Life Form is* Sparse *then the dominance goes to another* Life Form *which has a* Closed *or* Open *cover.*

This can be illustrated by the following example from A12:

> *What is normally called "Tree Savannah" consists of a closed herbaceous vegetative cover that forms the main layer, with a second layer of sparse trees projecting above. In this case, the use of the uppermost canopy concept would designate the trees as a dominant layer over the herbaceous layer. Because of the sub-condition of cover, sparse trees cannot be the dominant* Life Form *with the presence of the closed herbaceous layer. This concept must be carefully considered due to the in-built conditions in the classification system. If the user starts with the wrong main* Life Form, *i.e., sparse trees, the option to select* closed herbaceous *as second layer will not be available because the system excludes any closed vegetation layer if the main stratum is sparse.*

The following table summarizes the above criteria for determining the dominant *Life Form*:



Layering conditions for the dominant life forms are illustrated graphically below: *Trees* (Figure A), *Shrubs* (Figure B) and *Herbaceous/Forbs/Graminoids* (Figure C).

FIGURE A.

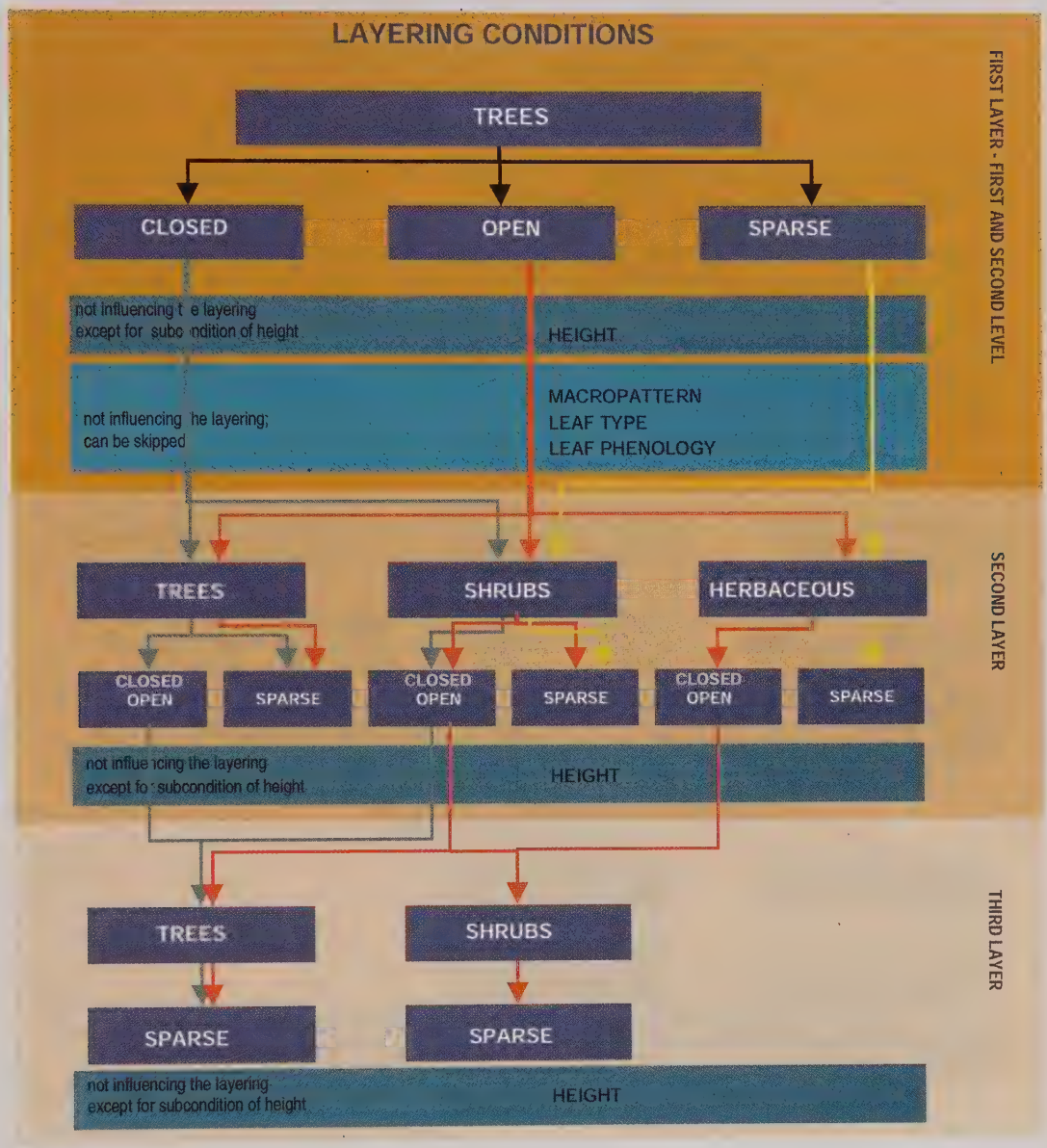

LAYERING CONDITIONS
FIRST LAYER - FIRST AND SECOND LEVEL
TREES
CLOSED
OPEN
SPARSE
not influencing t e layering
except for subc ndition of height
HEIGHT
not influencing he layering;
can be skipped
MACROPATTERN
LEAF TYPE
LEAF PHENOLOGY
SECOND LAYER
TREES
SHRUBS
HERBACEOUS
CLOSED OPEN
SPARSE
CLOSED OPEN
SPARSE
CLOSED OPEN
SPARSE
not influe ncing the layering
except fo subcondition of height
HEIGHT
THIRD LAYER
TREES
SHRUBS
SPARSE
SPARSE
not influencing the layering
except for subcondition of height
HEIGHT

FIGURE B.

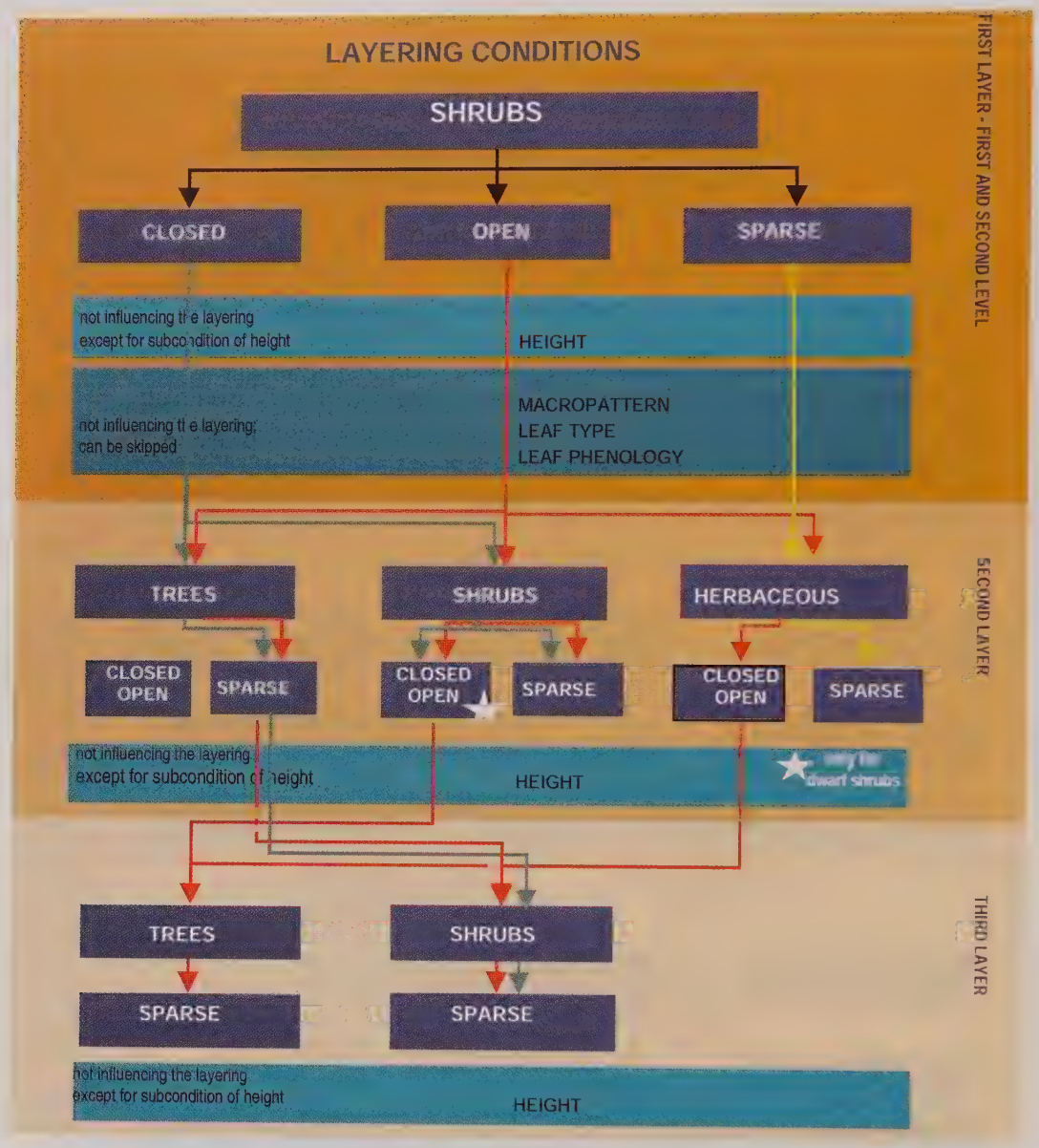
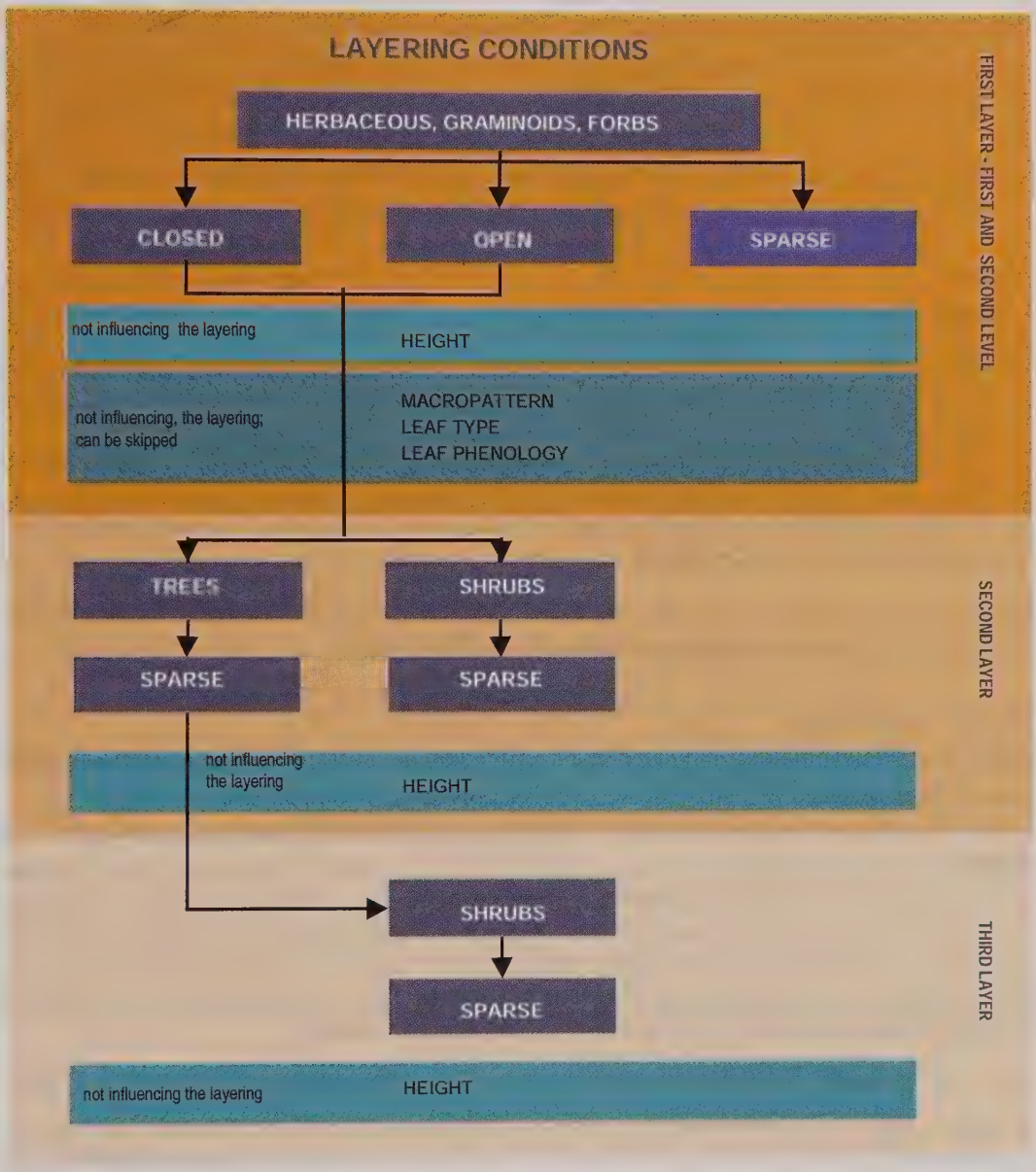

LAYERING CONDITIONS
SHRUBS
CLOSED
OPEN
SPARSE
not influencing the layering
except for subcondition of height
HEIGHT
not influencing the layering;
can be skipped
MACROPATTERN
LEAF TYPE
LEAF PHENOLOGY
FIRST LAYER - FIRST AND SECOND LEVEL
TREES
SHRUBS
HERBACEOUS
CLOSED
OPEN
SPARSE
CLOSED
OPEN
SPARSE
CLOSED
OPEN
SPARSE
not influencing the layering
except for subcondition of height
HEIGHT
only for
dwarf shrubs
SECOND LAYER
TREES
SHRUBS
SPARSE
SPARSE
not influencing the layering
except for subcondition of height
HEIGHT
THIRD LAYER

FIGURE C.


LAYERING CONDITIONS
HERBACEOUS, GRAMINOIDS, FORBS
CLOSED
OPEN
SPARSE
not influencing the layering
HEIGHT
not influencing, the layering; can be skipped
MACROPATTERN
LEAF TYPE
LEAF PHENOLOGY
FIRST LAYER - FIRST AND SECOND LEVEL
TREES
SHRUBS
SPARSE
SPARSE
not influencing the layering
HEIGHT
SECOND LAYER
SHRUBS
SPARSE
not influencing the layering
HEIGHT
THIRD LAYER

Woody (A12 and A24)

Defined as perennial plants with stem(s) and branches from which buds and shoots develop (Ford-Robertson, 1971). Semi-woody plants are included here (Eiten, 1968). Depending on the branching symmetry, a distinction is made between *Trees* and *Shrubs* (Strasburger *et al.*, 1983). With reference to the International Classification and Mapping of Vegetation (UNESCO, 1973), bamboos and tuft plants (palms, tree ferns, etc.) belong to this category. Depending on their height, they are classified as *Trees* or *Shrubs*.

Guidelines

The classifier Woody *can be applied in two cases:*

- *The vegetation is an intricate mixture of different* Life Forms *(e.g., trees and shrubs form a closed cover where its upper surface is so uneven that neither one nor more distinct separate layers of cover can be distinguished).*
- *The level of detail of the description of the class does not require a separation between* Trees *and* Shrubs. *In this case, the class indicates that woody vegetation is present without further specification into trees or shrubs.*

The first case is related to a specific structural aspect of vegetation, whereas the second one is related to the detail of information, which the user is able to define.

Trees (A12 and A24)

A tree is defined as a woody perennial plant with a single, well-defined stem carrying a more-or-less-defined crown (Ford-Robertson, 1971) and being at least 3 m tall.

Guidelines

A condition of Height *is applied to separate* Trees *from* Shrubs*: woody plants higher than 5 m are classified as* Trees. *In contrast, woody plants lower than 5 m are classified as* Shrubs. *This general rule is subject to the following exception: a woody plant with a clear physiognomic aspect of trees can be classified as* Trees *even if the* Height *is lower than 5 m but more than 3 m. In this case, a subcondition of physiognomic aspect is added to the* Height *condition.*

These are the recommended thresholds for Life Form characterization, but exceptions are allowed:

- *Plants essentially herbaceous but with a woody appearance (e.g., bamboos and ferns) are classified as* Trees *if the height is more than 5 m, and as* Shrubs *if the height is less than 5 m.*
- *For the classifier* Woody *(indistinct and/or intricate mixture of trees and shrubs), the higher limit is set at 7 m and the lower one at 2 m.*

Shrubs (A12 and A24)

These are woody perennial plants with persistent and woody stems and without any defined main stem (Ford-Robertson, 1971), being less than 5 m tall. The growth habit can be erect, spreading or prostrate.

Guidelines

Life Form of a plant is defined by its physiognomic aspect. This is the case when Woody *plants, subdivided into* Trees *and* Shrubs, *are distinguished from* Herbaceous *plants, subdivided into* Forbs *and* Graminoids, *and* Lichens/Mosses.

A condition of Height *is applied to separate* Trees *from* Shrubs*: woody plants higher than 5 m are classified as* Trees. *In contrast, woody plants lower than 5 m are classified as* Shrubs. *This general rule is subject to the following exception: a woody plant with a clear physiognomic aspect of trees can be classified as* Trees *even if the* Height *is lower than 5 m but more than 3 m. In this case, a subcondition of physiognomic aspect is added to the* Height *condition.*

These are the recommended thresholds for Life Form characterization, but exceptions are allowed:

- *Plants essentially herbaceous but with a woody appearance (e.g., bamboos and ferns) are classified as* Trees *if the height is more than 5 m, and as* Shrubs *if the height is less than 5 m.*
- *For the classifier* Woody *(indistinct and/or intricate mixture of trees and shrubs), the higher limit is set at 7 m and the lower one at 2 m.*

This category in A12 includes: other Woody plants which are not 'shrublike' (e.g., ground lianas), Welwitschia *and plants which are definitely not herbaceous (e.g.,* Agave *and cactoids).*

Herbaceous (A12 and A24)

Defined as plants without persistent stem or shoots above ground and lacking definite firm structure (Scoggan, 1978). There are two categories, depending on the physiognomy (Kuechler and Zonneveld, 1988; UNESCO, 1973), namely *Graminoids* and *Forbs.*

Guidelines

The classifier Herbaceous *can be applied in two cases:*

- *The vegetation is an intricate mixture of different* Life Forms *(e.g.,* Forbs *and* Graminoids*) forming a continuous layer of the two elements.*
- *The level of detail of the description of the class does not require a separation between* Forbs *and* Graminoids.

Forbs

All broad-leaved herbaceous plants in the common sense (e.g., sunflower, clover, etc., in A12) and all non-graminoid herbaceous plants (UNESCO, 1973). Therefore ferns, except tree ferns (Kuechler and Zonneveld, 1988), and very low, non-leafy succulents (Eiten, 1968) are included.

Guideline

The category applies where Forbs *comprise more than 75 percent of the overall herbaceous coverage.*

In A24, a further distinction can be made into *Rooted* and *Free-floating* Forbs.

Rooted (A24)

These are aquatic plants that are growing on a substrate but structurally supported by water (UNESCO, 1973;Cowardin, 1979).

Free-floating (A24)

Defined as a non-anchored plant that floats freely in the water or on the water surface, e.g., formations like common duckweed (*Lemna minor*) or water hyacinth (*Eichhornia crassipes*) (UNESCO, 1973; Cowardin, 1979).

Graminoids

All herbaceous grasses and other narrow-leaved grass-like plants that are not grasses according to the taxonomic definition (Kuechler and Zonneveld, 1988). Bamboos are technically grasses but they are Woody in form and therefore classed with Shrubs or Trees.

Guidelines

Graminoid vegetation is defined by the presence of more than 75 percent Graminoids in the herbaceous coverage. There is no upper limit of height: the only condition is the physiognomy of the plant.

Lichens/Mosses (A12 and A24)

Lichens are composite organisms formed from the symbiotic association of fungi and algae. They are found encrusting rocks, tree trunks, etc., and they are often found under extreme environmental conditions (Lawrence, 1989). In tundras of North America and Eurasia, lichens (e.g., *Cladonia* spp.) may cover large areas (Kuechler and Zonneveld, 1988).

Mosses are a group of photo-autotrophic land plants without true leaves, stems or roots, but with leaf- and stemlike organs, e.g., sphagnum (Gray, 1970). Several plants commonly called "mosses" in fact belong to other groups: reindeer moss is a lichen; Spanish moss is a vascular plant (parasite); and Irish moss is an algae (Lawrence, 1989).

Guidelines

This category is only applied if the other Life Forms *are not present and when Lichen/Mosses cover more than 20 percent. Otherwise they do not form a specific class but their presence can be mentioned in the description of another land cover class.*

Lichens *as specific class is applied when both Lichens and Mosses are present and when Lichens contribute 25 percent or more of the total cover.*

Mosses *as specific class is applied when both Lichens and Mosses are present and when Mosses contribute 25 percent or more of the total cover.*

A. COVER (A12 and A24)

The cover can be considered as the proportion of a particular area of the ground, substrate or water surface covered by a layer of plants, considered at the greatest horizontal perimeter level of each plant in the layer (according to Eiten, 1968). A distinction is made between *closed* (more than 60-70 percent), *open* (70-60 percent to 20-10 percent) and *sparse* (20-10 percent to 1 percent). The reason of expressing the cover through ranges instead of using absolute values will be explained in the respective Guidelines.

As herbaceous plants are seasonal in character, it has to be noted that the cover of herbaceous vegetation is always considered at the time of its fullest development.

Closed (more than 70-60 percent)

A layer of a certain *Life Form* covers more than (70-60) percent of a defined area. A closed cover composed of *Trees* or *Shrubs* has crowns interlocking, touching, or very slightly separated. In the last named case, the distance between two perimeters is no more than 1/6 of the crown average diameter (Eiten, 1968). The crowns can form an even or uneven closed canopy layer.

Guideline

If plants are growing in a defined area with the crowns touching each other, presuming that the crowns of a Woody Life Form *are round, the cover of the canopy will be approximately 78 percent. However, crowns are in reality often interlocking and small open spaces in the canopy are frequent. Therefore, in a closed canopy layer, the lower limit of closed vegetation is set at 60 percent. Because of the great variability of the horizontal character of closed vegetation, in particular the different crown shapes of the plant species, the range of values can vary from 60 to 70 percent.*

Open ((70-60) to (20-10) percent)

Between (70-60) and (20-10) percent of a defined area is covered by a certain *Life Form.* In the case of *Trees* and *Shrubs*, the crowns are usually not interlocking. The distance between the perimeters can range from very small up to twice the average diameter (Eiten, 1968).

This category is further subdivided into *Open* ((70-60) to 40 percent) and *Very Open (*40 to (20-10) percent).

Guideline

In the case of woody vegetation with a cover of between (70-60) and 40 percent, the plants are standing rather close together and, from a distance, they may appear to grow continuously (Kuechler and Zonneveld, 1988). To separate the two subclasses, the limit is set at 40 percent. The practical reason behind this is that at 40 percent coverage with Trees *the distance between two perimeters equals the mean radius of a tree crown (UNESCO, 1973).*

Sparse ((20-10) to 1 percent)

Between (20-10) and 1 percent of a defined area is covered by a certain layer of plants. The distance between two perimeters of a *Life Form* is more than twice the average perimeter diameter (Eiten, 1968). In many cases, a sparse *Life Form* might be associated with another *Life Form* of greater cover continuity, e.g., savannahs are characterized by sparse trees standing out from a herbaceous closed or open layer. Subdivision is made into *Sparse* ((20-10) to 4 percent) and *Scattered* (4 to 1 percent).

Guidelines

There are two reasons for the application of the range of 20 to 10 percent:

- *There is a great variability in the horizontal character of closed vegetation, namely different crown densities or crown shapes of the plant species (see also* closed*).*
- *Sparse cover is rarely homogenous but grows in clumps, and therefore cannot easily be defined as one single value.*

The classifier *Scattered* is only applicable if the total cover of all vegetation (that is all *Life Forms*) in the area equals or exceeds 4 percent.

B. HEIGHT (A12 and A24)

The height of a certain layer is measured from the ground to the average top of the *Life Form being* assessed (Kuechler and Zonneveld, 1988). The fact that single plants of one synusia differ from the average height can be ignored, apart from the fact that they can form their own layer (e.g., the emergents of a rainforest that tower above the rest).

Height subdivisions are: more than 30 m down to 3 m for *Trees*; 5 m to 0.3 m for *Shrubs*; and 3 m to 0.03 m for *Herbaceous*. Each class is further subdivided.

Guidelines

There is an overlap between the lower height limit for trees and the upper limit for shrubs, and also between the minimum height for shrubs and the maximum height for herbaceous.

Height classes are directly related to Life Forms *as height plays a complementary role in the definition of the structural classes. When a specific Height class is chosen, the user deliberately decides to give more emphasis to Height in the classification.*

C. SPATIAL DISTRIBUTION – MACROPATTERN (A12 only)

Spatial distribution, or Macropattern, is concerned with the horizontal distribution of the vegetation (Feoli *et al.*, 1991).

Macropattern is further subdivided into: *Continuous*, *Fragmented* and *Parklike Patches.*

Guidelines

The Macropattern *shows an ecological or a degradation aspect of vegetation (e.g., scattered vegetation in arid areas, agricultural encroachment inside forest areas, degradation due to overgrazing, etc.). In many classifications, one finds terms that are extremely subjective, like "Degraded Forests" or similar. The classification presented here is neutral in land cover description, without including ambivalent terminology. Therefore* Macropattern *is selected as a neutral classifier to describe the vegetation status:*

- *The classification presented here was built up for mapping purposes; therefore, spatial distribution of land cover is an important aspect; and*
- Macropattern *is easily detectable from remote sensing data (photographs and imagery), i.e., it has great "mapability."*

Macropattern *should thus be used to give supplementary ecological information (or to show a human-induced evolution aspect of natural vegetation).* ***The user has the option to skip this classifier if it is felt to be irrelevant information.***

Macropattern *is defined as* ***the horizontal spatial distribution of vegetation in a certain area****. It should not be confused with* Cover, *which defines the spatial arrangement of* Life Forms *(e.g., trees, shrubs, etc.).* Macropattern *describes the spatial arrangement of specific structural vegetation types (e.g.,* Closed Forest, Closed Shrubs*).*

The combinations between Cover *and* Macropattern *are unrestricted (this is nevertheless only valid for* Closed Cover *and* Open Cover, *as will be explained later. This means that, for instance, a closed tree formation (*Closed Forest*) can be either* Continuous *or* Fragmented *depending on its spatial distribution in the mapping unit.*

Because of this dimensional aspect, Macropattern *is linked to the mapping scale. This may seem to contradict the main classification concept explained earlier, which states that the elements of a classification system must be scale-independent.* ***To determine*** **Macropattern**, ***one should refer to the overall appearance of a vegetation formation in a certain area in a homogeneous landscape.*** *However, if one wants to be more precise or objective in the application of this classifier some specific rules are given below to help the user not familiar with this concept, in order to standardize interpretation. Because we are dealing with the practical application of this concept in a cartographic context, the concepts of* mixed units *and* minimum mappable areas *will be used.*

A certain structural vegetation type has a continuous Macropattern *if it covers more than 80 percent of the area inside the minimum mappable area.*

A certain structural vegetation type has a fragmented Macropattern *if it covers more than 20 percent but less than 80 percent inside the minimum mappable area. This situation is linked with the concept of* mixed unit. *Three cases are possible:*

- *Where the structural vegetation type (e.g., dense forest) covers more than 50 percent of the area and the other element (e.g., agricultural fields) less than 50 percent but more than 20 percent. In this case, the resulting unit will be a mixed unit with the fragmented dense forest as the dominant element (e.g., fragmented dense forest/agricultural fields).*
- *Where the structural vegetation type (e.g., dense forest) covers less than 50 percent but more than 20 percent of the area. The other element (e.g., agricultural fields) covers more than 50*

percent. In this case, the class is mixed, but the dominant class will be the agricultural fields (e.g., agricultural fields/fragmented dense forest).

- *When a unit contains three elements (e.g., fragmented dense forest, agricultural fields and bare areas) the rules for mixed units should be applied. In this case, it could be possible to have a structural vegetation type with a fragmented Macropattern as a single unit (e.g. fragmented dense forest 70 percent, agricultural fields 15 percent, and bare areas 15 percent. Neither of the minor elements reaches a cover of more than 20 percent of the unit; thus, the unit must be considered a single mapping unit of fragmented dense forest). This is the only case when a structural vegetation type with fragmented Macropattern must be considered as a single mapping unit. Even if theoretically possible, this case must be considered a very unusual one, and therefore should be avoided.*

The Continuous *or* Fragmented *classifiers are linked with* Closed Cover *or* Open Cover *(e.g., Closed Continuous Forest, Closed Fragmented Forest, Continuous Woodland or Fragmented Woodland). Fragmentation can be further subdivided into* Striped *and* Cellular *(e.g., tiger bush in the Sahel where Closed Shrubs are present in the interdunal areas, which can be represented as Fragmented (Striped) Closed Shrubs).*

The Macropattern Parklike Patches *is directly linked with the cover* Sparse. *This is simply redundant information. When the user defines the cover of a certain life form as* Sparse, *the only Macropattern available for this structural vegetation type is* Parklike Patches.

The Macropattern is preferentially used for Woody life forms (Trees, Shrubs). Herbaceous life forms (Graminoids, Forbs) can have a Macropattern, but this is subordinated to the absence of Woody life forms. Thus, when linear patches of dense shrubs (typical of tiger bush) are present together with dense herbaceous vegetation covering the space between the different patches, one can see it in two different ways: either as fragmented shrubs/herbaceous or fragmented herbaceous/shrubs. The abovementioned rule of preferentially favouring Woody life forms obliges the user to always give preference, in the application of the Macropattern, to the Woody component. Macropattern can be applied to Herbaceous life forms only when there is no significant presence of Woody life forms (Trees, Shrubs). For instance, patches of dense Herbaceous vegetation in sandy areas can be called fragmented herbaceous/sand.

A structural vegetation type is fragmented when the sizes of the patches of the vegetation are between 1/15 and 1/2 of the minimum mappable unit. This rule is a very artificial one and does not need to be strictly applied. This rule assists the user by providing some indication of how a fragmented Macropattern should look. If the patches were too small, then at a certain level they could coincide with the life form itself, thus contradicting the basic rule explained above (i.e., Macropattern *describes the specific arrangement of structural vegetation types and must not be confused with the cover of the life form).*

Continuous

A given cover can be *Open* or *Closed* but to be considered *Continuous,* the vegetation has to be spread over the area with regularity and without interval or break.

Guideline

A certain structural vegetation type has a Continuous Macropattern if inside the minimum mappable area it covers more than 80 percent of the area.

Fragmented

A given cover can be *Open* or *Closed* but it is interrupted in the sense of Striped or Cellular fragmentation.

Guidelines

A certain structural vegetation type has a fragmented Macropattern if inside the minimum mappable area it covers more than 20 percent but less than 80 percent. This situation is linked with the concept of mixed unit. Three cases are possible:

- *The structural vegetation type (e.g., dense forest) covers more than 50 percent of the area and the other element (e.g., agricultural fields) less than 50 percent but more than 20 percent. In this case, the resulting unit will be a mixed unit with the fragmented dense forest as the dominant one (e.g., fragmented dense forest/agricultural fields).*

- *The structural vegetation type (e.g., dense forest) covers less than 50 percent but more than 20 percent of the area. The other element (e.g., agricultural fields) covers more than 50 percent. In this case, the class is mixed but the dominant class will be the agricultural fields (e.g., agricultural fields/fragmented dense forest).*

- *When a unit contains three elements (e.g., fragmented dense forest, agricultural fields, and bare areas) the rules for mixed units should be applied. In this case, it could be possible to have a structural vegetation type with a fragmented Macropattern as single unit (e.g., fragmented dense forest, 70 percent; agricultural fields, 15 percent; and bare areas, 15 percent. Neither of the two minor elements reaches a cover of more than 20 percent of the unit; thus, the unit must be considered a single mapping unit of fragmented dense forest). This is the only case when a structural vegetation type with fragmented Macropattern must be considered as a single mapping unit. Even if theoretically possible this case must be considered a very unusual one, therefore should be avoided.*

Parklike Patches

In the case of woody vegetation, *Parklike Patches* signifies that trees and shrubs grow singly or in small groups as in parklands and in savannahs. When herbaceous vegetation is present, it signifies disconnected patches (Kuechler and Zonneveld, 1988).

Guideline

The Macropattern Parklike Patches *is directly linked with the cover* Sparse. *This is simply redundant information. When the user defines the cover of a certain life form to be* Sparse, *the only Macropattern available for this structural vegetation type is* Parklike Patches.

C. WATER SEASONALITY (A24 only)

Water Seasonality refers to the type of persistence of the water at or near the surface. A subdivision is made into three classes: *(Semi-)Permanent* (approximately four months a year, or more than a specific season), *Temporary* or *Seasonal* (less than four but more than two months a year, or during a specific season) and *Waterlogged.*

(Semi-)Permanent

In this class, areas are considered which are covered by water for a substantial period, but which is not directly linked to a specific season. The class can be further subdivided into two subclasses: one where water is persistent the whole day (no tidal influences), and one where there is a tidal influence.

Temporary or Seasonal

This class covers areas that are regularly flooded, but where the water cover does not remain for a substantial period of time or other than for a particular season.

Waterlogged

The water table is very high and at or near the surface. These areas could be occasionally flooded, but the main characteristic is the high level of the water table (e.g., bogs).

D. LEAF TYPE (A12 and A24)

Leaf type is applied only when characterizing *Trees* and *Shrubs*. A distinction is made between *Broadleaved*, *Needleleaved* and *Aphyllous*.

Broadleaved

This refers to trees and shrubs of the botanical group Angiospermae, with Gingko (*Gingko biloba*) as an exception, as it taxonomically belongs to the Gymnospermae. Both *Evergreen* and *Deciduous* species belong to this category.

Needleleaved

This refers to trees and shrubs of the botanical group Gymnospermae (Ford-Robertson, 1971), carrying typical needle-shaped leaves.

Guideline

*Both evergreen conifers like pines (*Pinus *spp.), hemlock (*Tsuga *spp.), and firs (*Abies *spp.), etc., as well as deciduous conifers like the larch (*Larix *spp.), are included in A12. It is also applied to scale-like leaves, especially leaves of arbor vitae (*Thuja occidentalis*). Contrary to usual definitions, this category includes all plants with needle-like leaves, even though they are not conifers, such as some Australian acacias (e.g.,* Acacia asparagoides*).*

Aphyllous

This category includes plants without any leaves and plants that apparently do not have leaves in the common sense. In the first case, photosynthesis takes place through other organs, like stems, branches and twigs; in the latter case, the leaves are very short-lived or extremely reduced to scales and thorns.

Guideline

Characteristic genera in A12 are: Casuarina, Euphorbia, Tamarix *and many others mostly found in arid and semi-arid regions (Kuechler and Zonneveld, 1988).*

E. LEAF PHENOLOGY (A12 and A24)

The leaf phenology is for the general behaviour of woody plants throughout the year. Two types have to be distinguished: *Evergreen* and *Deciduous*. A further distinction is made between *Mixed* and *Semi-Deciduous* or *Semi-Evergreen*. The leaf phenology of herbaceous plants is classified through the mixed category. A separation can be made between *Perennial* and *Annual* vegetation.

Evergreen

This term as such describes the phenology of perennial plants that are never entirely without green foliage (Ford-Robertson, 1971).

Guideline

For this class to be applicable, there must be a whole layer that is more than 75 percent evergreen vegetation.

Deciduous

This applies to the phenology of perennial plants which are leafless for a certain period during the year (Ford-Robertson, 1971). The leaf shedding usually takes place simultaneously in connection with the unfavourable season (UNESCO, 1973).

Guideline

For this class to be applicable, there must be a whole layer that is more than 75 percent deciduous vegetation.

Mixed (Woody Life Form)

This category is limited exclusively to a layer with a mixture of broadleaved deciduous and needleleaved evergreen vegetation (Kuechler and Zonneveld, 1988).

Guideline

Within this combination, it is necessary that each of the two components occupy at least 25 percent of the area.

Semi-Deciduous or Semi-Evergreen

This applies to the broadleaved category, as under tropical conditions *deciduousness* is difficult to define, especially as seasonal variation influences the time of leaf-shedding; plants are deciduous in certain areas, evergreen in others.

Guideline for Semi-Deciduous

This term applies to a combination of broadleaved deciduous that is dominant and broadleaved evergreen being more than 25 percent.

Guideline for Semi-Evergreen

This term applies to a combination of dominant broadleaved evergreen and with broadleaved deciduous being more than 25 percent.

Mixed (only for Forbs and Graminoids)

This category is limited to a layer with a mixture of perennial or annual herbaceous plants.

Perennial: plants living more than one year

Annual: plants living one year.

Guideline

With both perennial and annual plants being present, each type must cover at least 25 percent of the area.

F. STRATIFICATION (A12 and A24)

Stratification, or layering, is defined as the vertical layering of vegetation. It should not be confused with Macropattern, which describes the horizontal distribution of Life Forms, nor with Cover, which describes the presence of one single Life Form.

Guidelines

The user can describe up to three layers for (Semi-)Natural Terrestrial Vegetation (A12) *and two layers (including the main layer) for* Aquatic or Regularly Flooded Vegetated Areas (A24). *The limited number of layers at their disposal may disappoint users, but the classifier* **Stratification** ***should contribute to the structural definition of a vegetation class****. This means that this classifier must consider all the possible combinations with the main* Life Form *selected and its* Cover *(e.g., if we can have layering for Closed Trees, the same must be valid for Closed or Open Shrubs or Closed Graminoids, etc.). The layering is an active component of the class set-up; it is not a mere descriptive (optional and unsystematic) item of the class. The proposed classification allows the user to first build up a land cover class with the use of the classifier* Stratification *and, if more details are wanted, add a user's description to the standard one, which can contain information on any additional layers/strata.*

Some limitations in the use of the classifier Stratification *have been introduced in order to avoid class combinations that are irrelevant from the structural point of view. These limitations prevent introduction of elements that not crucial for the determination of the structural aspects of a land cover class. These elements can be added in the class description in the Legend (see Legend – Edit). These limitations have the practical purpose of reducing the number of possible combinations of classifiers, which otherwise could lead to creation of an even larger number of classes that would all have the same structural meaning. All limits to the use of* Stratification *are built into the software program.*

From a practical point of view in the use of the Stratification *concept, it is important to recognize two types of* Stratification*:*

(a) where the second stratum consists of the ***same*** Life Form *as the main stratum (e.g., trees-trees and shrubs-shrubs); and*

(b) where the second stratum consists of a ***different*** Life Form *(e.g., trees-shrubs).*

The second case is quite straightforward and does not present any difficulty in the selection of classifier. The first case needs additional explanation. In the case of a dominant Life Form *of* Trees *with a second stratum of* Trees*, it is important that these layers are clearly distinguishable one from the other (e.g., second stratum of Trees Emergent over a Closed Tree canopy; these emergents must not be part of the discontinuity of the Closed Tree canopy but a clearly distinct layer).* ***The sub-condition of*** **Height** ***will pre-set the available choices of Height for a second, and (for A12 only) a third, layer*** *(e.g., with a main stratum of Closed Low Trees (3-7 m), the emergents to be defined in the second stratum cannot have the same height (option 3-7 m is therefore not available) because the Sparse Trees of the second layer have to be taller).*

The Height condition explained above depends on the detailed option for Height chosen for the main stratum; it is not applied if the general Height class is selected. If the user selects the general Height class for the main stratum then for subsequent strata the general Height classes are the only options available.

The main conditions applied for Stratification/Layering *are the following:*

a1) Forbs *and* Graminoids *are considered always together as* Herbaceous.

a2) *For* Trees *three strata including the main, can be considered in A12 (e.g., a main Closed Tree layer with a second, lower, Closed to Open Tree layer, and a third Sparse Tree layer of emergents would be termed a Multi-Layered Forest With Emergents), and in A24 two strata including the main are allowed.*

a3) *When the main stratum is* Closed Trees *or* Open Trees *and there is a second layer* Sparse Trees, *then the* Height *of the second layer must be higher, i.e., emergent; if they are lower, they are not considered as an independent stratum.*

a4) *For* Shrubs, *the number of strata with the same* Life Form *is two, including the main stratum.*

a5) *For* Herbaceous *only one stratum is possible.*

a6) Lichens/mosses *are not described in the layering.*

a7) *If the main stratum is* Trees *and the* Cover *is* Open, *then it is impossible to have the same* Life Form *with Cover Open To Closed with a different height as a second stratum (e.g., Open High Trees with Open Low Trees is impossible).*

a8) *If the main stratum is* Shrubs *and the* Cover *is* Closed *or* Open, *then it is impossible to have the same* Life Form *with Cover Open To Closed with a different height as a second stratum (e.g.. Open High Shrubs with Closed To Open Low Shrubs is impossible). The only exception to this rule is when the second stratum consists of* Dwarf Shrubs.

and

b1) *If the cover of the main stratum is* Closed Trees *or* Closed Shrubs *then any* Herbaceous *layer possibly present is not considered or described (this can be added as a user-defined description).*

b2) Sparse Herbaceous *is never considered as second layer except when the main layer is* Sparse Trees *or* Sparse Shrubs *(but it can be added as a user-defined description).*

b3) *If the main stratum is* Shrubs *or* Herbaceous, *only one layer of trees can be considered; this is linked with the criterion of dominance as described earlier, because the* Trees *or* Shrubs *can be only* Sparse.

b4) *Only two layers other than the main layer are considered for* Terrestrial Vegetation (A12) *and only one additional strata for* Aquatic Vegetation (A24).

T. FLORISTIC ASPECT (A12 and A24)

This attribute has two major divisions based on whether the name is derived from a single plant species or from a group of plants. In the first case, a further subdivision is possible into *Dominant Species* (Height, Cover or combination of both) or *Most Frequent Species.* The second subdivision is subdivided again into *Plant Groups* (e.g., Braun-Blanquet) and *Plant Groups Derived Without Statistical Methods* (e.g., same ecological significance, same geographic distribution, same dynamic significance, etc.). The specific name of the *Floristic Aspect* can be added using the *User-defined Attribute* option in the Legend Module.

CULTIVATED AND MANAGED AREAS (A11 and A23)

A. LIFE FORM OF THE MAIN CROP (A11 and A23)

A *Life Form* is a group of plants having certain morphological features in common (Kuechler and Zonneveld, 1988).

For further classification the following growth form criteria are used (Kuechler and Zonneveld, 1988; Strasburger *et al.*, 1983):

- Duration of the crop (*Trees*);
- Branching symmetry of woody plants (to divide *Trees* from *Shrubs*); and
- Physiognomy of *Herbaceous* plants (to distinguish *Graminoids* from *Non-Graminoids*).

Guidelines

Contrary to Natural and Semi-Natural Vegetation (A12), Cultivated Areas *are not described by classifiers such as Height or Cover. They are classified exclusively according to their morphology.*

Contrary to the major land cover type A11, in A23 a distinction is only made between Graminoids *and* Non-Graminoids.

The main crop is entirely defined as the vegetative cover that is ***not marginal****, i.e., which covers a considerable area (more than 15 percent of the surface), or which has a high economic revenue and which comprises the* ***uppermost canopy****. A second and/or third crop type can be specified, but these crops have a lower canopy than the main crop or they are a marginal crop, i.e., cover less than 15 percent of the surface or has a low economic revenue.*

Trees (A11 only)

A tree is defined as a woody perennial plant with a single, well defined stem carrying a more-or-less-defined crown (Ford-Robertson, 1971). The plants often form a distinct block and are often planted in a regular spacing or pattern (e.g., orchards, and nursery stock). The duration of the crop cover usually lasts many years.

Guidelines

This category includes:

- *Broadleaved trees which are used for harvesting part(s) of the trees (e.g., fruits or nuts).*
- *Any kind of nursery stock, ornamental trees, fruit trees, hedging plants, conifers, etc.*
- *Regularly planted shade trees.*

A further distinction is made as follows:

Broadleaved

This refers to Trees of the botanical group Angiospermae, with Gingko (*Gingko biloba*) as an exception, as it belongs taxonomically to the Gymnospermae. Both evergreen and deciduous species come into this category.

Needleleaved

This refers to Trees of the botanical group Gymnospermae (Ford-Robertson, 1971) carrying typical needle-shaped leaves. Both evergreen and deciduous species come into this category.

Evergreen

This refers to the phenology of perennial plants that are never entirely without green foliage (Ford-Robertson, 1971).

Deciduous

This refers to the phenology of perennial plants which are leafless for a certain period during the year (Ford-Robertson, 1971). The leaf shedding usually takes place simultaneously in connection with the unfavourable season (UNESCO, 1973).

Shrubs (A11 only)

A shrub is a woody perennial plant with persistent and woody stems and without any defined main stem (Ford-Robertson, 1971). The growth habit can be erect, spreading or prostrate. The plants often form a distinct block and are often planted in a regular spacing or pattern (e.g., orchards, and nursery stock).

Guidelines

This category includes:

- *Shrubs used for harvesting the fruits, berries, leaves, etc., such as vine, cotton, coffee, cocoa, tea and soft fruits (currants, blackberries, etc.).*
- *Pineapple as a succulent plant is included here due to its appearance.*
- *Any kind of nursery stock with the plants mentioned above.*

A further distinction is made as follows:

Broadleaved

This refers to Shrubs of the botanical group Angiospermae, with Gingko (*Gingko biloba*) as an exception, as it belongs to the Gymnospermae taxonomically. Both evergreen and deciduous species come into this category.

Needleleaved

This refers to Shrubs of the botanical group Gymnospermae (Ford-Robertson, 1971) carrying typical needle-shaped leaves. Both evergreen and deciduous species come into this category.

Evergreen

This refers to the phenology of perennial plants that are never entirely without green foliage (Ford-Robertson, 1971).

Deciduous

This refers to the phenology of perennial plants which are leafless for a certain period during the year (Ford-Robertson, 1971). The leaf shedding usually takes place simultaneously in connection with the unfavourable season (UNESCO, 1973).

Herbaceous (A11 only)

This applies to plants without persistent stem or shoots above ground and lacking definite firm structure (Scoggan, 1978). The cover duration is limited to the harvest stage. A further distinction is made between *Graminoids* and *Non-Graminoids* (Kuechler and Zonneveld, 1988).

Graminoids (A11 and A23)

This includes all grasses and other narrow-leaved, grass-like plants that are not grasses according to the taxonomic definition (Kuechler and Zonneveld, 1988).

Guidelines (A11)

The following crops are included:

- *Cereals (e.g., wheat, millet, sorghum, maize, dryland rice) and sugar cane.*
- *Bamboos are also included here, in contrast to the* Natural and Semi-Natural Vegetation *land cover type* (A12).

Guidelines (A23)

The following crops are included:

- *Rice, cultivated as deepwater rice or tidal rice.*
- *Reed species.*

Non-Graminoids (A11 and A23)

This includes all herbaceous plants which are not *Graminoids*, i.e., it includes species that do not belong to the grasses according to the taxonomic definition, but excludes narrow-leaved, grass-like plants considered *Graminoid* for the purposes of classification here (Kuechler and Zonneveld, 1988).

A lot of species in A23 cover water surfaces with a large amount of biomass.

Guidelines (A11)

The following crops are included:

- *Root and tuber crops, pulses and vegetables, some fodder crops (e.g., certain legumes), and fibre crops (e.g., flax).*
- *Bananas as a tree-like herbaceous plant, in contrast to the* Natural and Semi-Natural Vegetation *land cover type (A12).*
- *Hops as a perennial herbaceous vine.*

A. LIFE FORM MANAGED LANDS (A11 only)

Urban Vegetated Area

This class includes vegetated areas that are enclosed by any kind of urban construction. These areas form isolated patches within the urban area. According to the dominating *Life Form* of the particular urban vegetated, area a further distinction can be made between:

- *Parks* where the dominating life form is trees. These parks may appear natural but the distribution of the trees and other present life forms is designed.
- *Parklands,* characterized by cover dominated by (ornamental) herbaceous vegetation (e.g., Forbs and Graminoids) with scattered groups of trees and/or shrubs.
- *Grass dominated areas* (Lawns) dominated by Graminoids. If trees and/or shrubs are present then they form a linear pattern surrounding the Graminoid-dominated area(s).

B. SPATIAL ASPECT – FIELD SIZE AND DISTRIBUTION (A11 and A23)

The *Spatial Aspect* describes cultivated fields in terms of *field size* (e.g., dimension) and their *distribution.*

Field Size (A11 and A23)

This class can be applied indicatively. A distinction is made between *Large-to-Medium-Sized Fields* and *Small-Sized Field(s).* However, this does **not** refer to large-, medium- or small-scale farming, because it does not relate to the overall size of the farm holding.

The following distinctions are made:

- Small-sized fields: less than 2 ha
- Medium-sized fields: 2 - 5 ha
- Large-sized fields: more than 5 ha.

Spatial Distribution (A11 and A23)

Spatial Distribution, or Macropattern, is concerned with the horizontal spatial arrangement of the field(s) within a defined area. A distinction is made between *Continuous* and *Scattered* field(s).

Guideline

Spatial Distribution is the horizontal pattern of cultivated fields in a certain area. It can be easily measured by considering the distance between a field and the next field. A further distinction can be made into three classes: Continuous, Scattered Clustered *or* Scattered Isolated.

Continuous

A given crop cover extends over an area without interval or break.

Guidelines

Continuous describes a continuum of more than 50 percent of cultivated fields. In this case the land cover mapping unit may be single (inside the mapping unit the fields take up more than 80 percent) or mixed (the fields occupy 51-80 percent of the mapping unit). Generally, when the fields occupy 51-80 percent of the mapping unit, the area in between the fields can be considered as part of the cultivated area by the user or the user can decide to make a mixed mapping unit depending upon which land cover features the user wants to highlight.

Scattered Clustered and Scattered Isolated

The Spatial Distribution is *Scattered Clustered* or *Scattered Isolated* when, within the cultivated fields' area, other land cover types are present.

Guidelines

- *Where the percentage of fields is more than 20 percent but less than 50 percent, it is* ***Scattered Clustered****; this means that the resulting mapping unit is a mixed land cover class of a cultivated area with another land cover class. If the unit is composed of two land cover classes the cultivated area class is always the secondary class in the mixed unit, and both components need to be defined in the legend (e.g., 60 percent of semi-natural vegetation and 40 percent of fields).*
- *Where the percentage of fields is more than 10 percent and less than 20 percent, it is* ***Scattered Isolated****; this means that the resulting mapping unit is a mixed land cover class where the dominant class is not "scattered isolated". It is the only case where a class comprising less than 20 percent is present in a mixed mapping unit.*

C. CROP COMBINATION (A11 and A23)

The dominant crop may be appearing solely or in combination with other crops. A distinction is made between *Single Crop* and *Multiple Crops* in A11. In A23, the environment of the one or two additional herbaceous crop(s) can be specified.

Single Crop (Monoculture)

This refers to a cultivation system in which a single crop species covers a plot of land, i.e., a monocultural cropping system. The cover duration is limited by the harvest stage.

Guidelines

- *In the case of* ***annuals****, the crop covers the land only part of the year.*
- *In the case of* ***perennials*** *the crop covers the land throughout the year and is harvested after several years or part of the crop is harvested every year.*

Multiple Crop (Intercropped)

Cultivation of two or three crops which are growing simultaneously or with a period of overlap or sequentially on the same field. Crop intensification is both in time and spatially (vertical and horizontal). No horizontal spatial arrangement of the crops (e.g., rows, strips or no arrangement) is considered.

Guideline

The Multiple Crop system can be further subdivided into One Additional Crop *and* More Than One Additional Crop. *They can be specified by* Life Form *and coincidence of their planting time with the main crop.*

Simultaneously

More than one crop is cultivated at the same time in a defined area. This is often indicated as mixed cropping. Therefore the different crops can be intermingled or they grow in distinct patterns on the same field.

Guidelines

Mixed annual crops are cultivated on one piece of land. For example: Legumes are often combined with Non-Legumes.

In the case of perennial crops (trees and shrubs), cash crops are interplanted during the period of establishment of the main crop. At a later stage the interplanted crops might be replaced by cover crops (Euroconsult, 1989).

Overlapping

Planting or sowing one crop into another crop which has reached an advanced growing stage but before the harvest of the first crop (Lipton, 1995).

Guideline

This class applies only to crops with briefly overlapping growing periods. An overlap which lasts for the whole cultivation period (e.g., if annual or biennial plants are planted into a stand of perennial plants) is considered Simultaneous. An example of crops with an overlapping period is when root crops are planted into a stand of cereals.

Sequential

The growing of two or more crops in sequence on the same field within one growing season. The succeeding crop is planted after the preceding one is harvested.

In the Aquatic or Regularly Flooded Cultivated Areas, a distinction is made between **One Additional Crop** and **Two Additional Crops**. These additional crops are always herbaceous but their growing environment can be specified, i.e., whether it is *aquatic or regularly flooded* or *terrestrial*. The cover duration of these additional herbaceous crops is limited to the harvest stage similar to the Terrestrial Cultivated Areas.

The cultivation of additional crops is either simultaneous with the main crop or in sequence on the same field as specified by the Cover-related Cultural Practices. Crop intensification is both temporally and spatially (vertical and horizontal). No horizontal spatial arrangement of the crops (e.g., rows, strips or no arrangement) is considered.

Guideline

If the option Sequential *is selected under* Cover-related Cultural Practices, *the additional crop can be either aquatic or terrestrial. If the option* Relay Intercropping *is selected, the additional crop grows at the same time as the main crop on the field and therefore the environment can only be aquatic.*

C. COVER-RELATED CULTURAL PRACTICES – WATER SUPPLY (A11 only)

A distinction is made between *rainfed*, *post-flooding* and *irrigated* cultural practices.

Rainfed Cultivation

Crop establishment and development is completely determined by rainfall.

Post-Flooding Cultivation

After rainwater has flooded the field, the water infiltrated into the soil is used intentionally as a water reserve for crop cultivation. The crop(s) use(s) this water reserve for establishment.

Irrigated

Any of several means of providing an artificial regular supply of water, in addition to rain, to the crop(s).

This category is further subdivided into the main irrigation methods:

- *surface irrigation*;
- *sprinkler irrigation*;
- *drip irrigation*.

Guidelines

Under Irrigated, *systems are also included in which an additional watergift depends on the actual rains and in which this watergift is essential for establishment and/or flowering of the crop. The aim of the additional watergift is to help the plants through a period of drought-stress (examples of this practice can be found in (semi-)arid climates).*

Surface Irrigation

Water is supplied to the field(s) to form a water layer that infiltrates slowly into the soil. The field may be wetted completed (borders, basins) or partly (furrows, corrugations). The water layer may be moving during irrigation (flow irrigation) or it may be mainly stagnant (check irrigation).

Sprinkler Irrigation

Water is pumped up from a source into a closed distribution network and then conveyed over the soil surface and crops. The irrigation water is applied by means of rotating sprinklers, perforated pipes, sprayers, or spinners that are connected to the network. The distribution networks may be permanent, portable or a combination of the two.

Drip Irrigation

This type of irrigation is also called trickle, dribble or localized irrigation. The water is applied at very low pressure through a network of plastic tubes running along the surface or buried. The network consists of main lines and laterals (Euroconsult, 1989). The water trickles onto the soil near the plant(s) at a confined spot.

D. COVER-RELATED CULTURAL PRACTICES – CULTIVATION TIME FACTOR (A11 only)

This classifier indicates for how much of the growing season(s) the land is covered by crops. A distinction is made between *shifting cultivation, fallow system* and *permanent cultivation.*

Shifting Cultivation

This describes the growing of crops for a few years on selected and cleared plots, alternating with a lengthy period of vegetative fallow when the soil is rested. The land is cultivated for less than 33 percent of the time (Ruthenberg, 1980). This cover by is followed by the vegetative and/or bare cover of the fallow period that can also last for several years (Shaner *et al.*, 1982).

Guidelines

The traditional system of the shifting cultivation results in various cover appearances (WAU, 1985)

1. *The existing vegetation on plots is cleared and burnt afterwards. Therefore the lower herbaceous vegetation layer is removed, followed by partial tree and shrub removal. Trees that deliver fruits to harvest are sometimes left. Tree stems might remain as a frame for later yam production. During this period, hardly any vegetation is left. These cleared plots are characteristically surrounded by land which is covered with primary and/or secondary "Natural or Semi-Natural Vegetation."*

2. *In the next phase crops cover the land. Because this production system is extensive, the crop cover might be mixed with spontaneous re-growth of vegetation that developed soon after the plot was burnt. In general, cereals are sown first followed by root and tuber crops. Sometimes root and tuber crops are planted immediately. A common worldwide crop combination starts with cereals, like maize or rice, later interplanted with a root crop, like cassava, or bananas, before the cereal is harvested (see also* overlapping crops*).*

3. *After the cultivation period is completed, the secondary semi-natural vegetation starts to fully develop. The amount of this type of semi-natural vegetation increases steadily. As soon as this secondary vegetation dominates the cultural plants, the area is no longer classed under "Cultivated Terrestrial Areas," but under* Natural and Semi-Natural Vegetation.

Fallow System

An agricultural system with an alternation between a cropping period of several years and a fallow period. The land is cultivated for between 33 and 66 percent of the years, which means a percentage of 50 percent is given by three, five or ten years of crop cover followed by three, five or ten years of fallow vegetative cover (Ruthenberg, 1980).

Guidelines

Because the fallow period is short, the cover consists mostly of grass and light bush vegetation. Areas covered with a distinct closed fallow vegetation without visible field delineations are classed under Natural and Semi-Natural Terrestrial Vegetation. *These visible field divisions are characteristic of* Fallow Systems. *Annual and biennial crops dominate the cover of this cultivation system. The cover of a fallow system is composed of a staple crop (like millet or maize), or a dominating cash crop (like cotton, groundnut, rice or tobacco), and a fallow area.*

Permanent Cultivation

This applies to the growing of crops that are not replanted for several years after each harvest (e.g., trees and shrubs). The crop should cover the land for at least two years. The

first harvest takes usually place after one year or later. Under this cultivation system the land is cultivated for more than 66 percent of the years (Ruthenberg, 1980).

Guidelines

In the case of annual plants, the crop covers the land only part of the year and is followed by a short fallow period or by another crop or covercrop. Examples are vegetables and rice.

In the case of perennials, the crop covers the land throughout the year.

The following crops are included (WAU, 1985):

- *woody perennials such as rubber, cacao, coffee, etc;*
- *tree-like crops such as oil palm and coconut;*
- *herbaceous perennials such as bananas, sugar cane, grasses, etc; and*
- *pineapple.*

D. COVER-RELATED CULTURAL PRACTICES – FALLOW PERIOD (A23 only)

A distinction is made between *Relay Intercropping* and *Sequential cultivation.*

Relay Intercropping

Planting or sowing one crop into another, maturing crop (Ruthenberg, 1980).

Sequential

The growing of two or more crops in sequence on the same field within one growing season. The succeeding crop is planted after the preceding one is harvested.

S. CROP TYPE (A11 and A23)

The crop type can be added optionally with different levels of detail. Initially a distinction is made between *Food Crops* and *Non-Food Crops*. A further subdivision is made specifying the most common crop species: Food Crops can be differentiated into *Cereals, Roots and Tubers, Pulses and Vegetables, Fruits and Nuts, Fodder, Beverages* and *Other*.

Non-Food Crops comprise *Industrial Crops, Wood/Timber* and *Other Non-Food Crops*. The species are grouped according to the main product being harvested.

For A11 the following groupings have been made:

Food Crops

Food Crops can be differentiated into *Cereals, Roots and Tubers, Pulses and Vegetables, Fruits and Nuts, Fodder, Beverages* and *Other*.

Cereals

In addition to Cereals in the narrow sense, the so-called pseudo-cereals are also included:

- Amaranthus (*Amaranthus* spp.)
- Barley (*Hordeum vulgare* L.)
- Chenopodium (*Chenopodium* spp.)
- *Fagopyrum* spp.
- Maize (*Zea mays* L.)
- Millets
- Oats (*Avena sativa* L.)
- Rice (*Oryza* spp.)
- Rye (*Secale cereale* L.)
- Sorghum (*Sorghum bicolor* (L.) Moench)
- Wheat (*Triticum* spp.)
- Other cereals

Roots and Tubers

- Cassava or Manioc (*Manihot esculenta* Crantz)
- Potato (*Solanum tuberosum* L.)
- Sweet potato (*Ipomoea batatas* (L.) Lam)
- Yam (*Dioscorea* spp.)
- Other roots and tubers

Pulses and Vegetables

- Asparagus (*Asparagus officinalis* L.)
- Beans (*Phaseolus* spp., *Vigna* spp.)
- Cabbages and Cauliflower (*Brassica* spp.)
- Carrot (*Daucus carota* L.)
- Chickpea (*Cicer arietinum* L.)
- Cucumbers (*Cucumis sativus* L.)
- Lentil (*Lens culinaris* Medicus)

- Lettuce (*Lactuca sativa* L.)
- Melons
- Onion (*Allium cepa* L. var. *cepa*)
- Pea (*Pisum sativum* L.)
- Pumpkins and squashes (*Cucurbita* spp.)
- Tomatoes (*Lycopersicon esculentum* M.)
- Other pulses and vegetables

Fruits and Nuts

- Almond (*Prunus amygdalus* Batsch)
- Apple (*Malus domestica* Borkh.)
- Avocado (*Persea americana* Mill.)
- Banana (*Musa* spp.)
- Cashew (*Anacardium occidentale* L.)
- Citrus Fruits (*Citrus* spp.)
- Coconut (*Cocos nucifera* L.)
- Date Palm (*Phoenix dactilifera* L.)
- Fig (*Ficus carica*)
- Grapes (*Vitis vinifera*)
- Groundnut (*Arachis hypogaea* L.)
- Guava (*Psidium* spp.)
- Hazelnut (*Corylus* spp.)
- Macadamia (*Macademia* spp.)
- Mango (*Mangifera indica* L.)
- Papaya (*Carica papaya* L.)
- Peach (*Prunus persica* (L.) Basch)
- Pear (*Pyrus communis*)
- Pineapple (*Ananas comosus* (L.) Merr.)
- Pistachio (*Pistacia vera* L.)
- Plum (*Prunus domestica* L.)
- Other fruits and nuts

Fodder

As there is an enormous list of species of fodder plants (Rehm and Espig, 1991) a division is only made into fodder grasses and fodder legumes. Fodder as a by-product of other crops is not considered here.

- Fodder grasses
- Fodder pulses
- Other fodder crops

Beverages and Stimulants

This includes also stimulants that are not beverages. Not included are beverages produced from fruit crops even if this is the main use in certain regions. Therefore grapes, citrus and others are listed under *Fruits and Nuts.*

- Cocoa (*Theobroma cacao* L.)
- Coffee (*Coffea* spp.)
- Hops (*Humulus lupulus* L.)
- Tea (*Camellia sinensis* (L.))
- Tobacco (*Nicotiana tabacum* L.)
- Other beverages

Non-Food Crops

Non-Food Crops comprise *Industrial Crops* and *Wood/Timber crops.*

Industrial Crops

This class includes crops, which provide raw materials that generally have to pass further mechanization or industrial processing, like fibre crops and oil crops. Oils that can be considered as by-products, for example oil from grain embryos or from the seeds of vegetables, fibre plants, etc., are not mentioned here.

- Coconut (*Cocos nucifera* L.)
- Castor (*Ricinus communis* L.)
- Cotton (*Gossypium* spp.)
- Groundnut (*Arachis hypogaea* L.)
- Hemp (*Crotolaria juncea* and *Cannabis sativa* L.)
- Jute (*Corchorus* spp.)
- Oil palm (*Elaeis guineensis* Jacq.)
- Olive (*Olea europaea* L.)
- Rubber (*Hevea* spp.)
- Safflower (*Carthamus tinctorius* L.)
- Sesame (*Sesamum indicum* L.)
- Sisal (*Agave* spp.)
- Soybean (*Glycine max* Merr.)
- Other industrial crops

Wood/Timber

- Acacia (*Acacia* spp.)
- Eucalypt (*Eucalyptus* spp.)
- Pine (*Pinus* spp.)
- Poplar (*Populus* spp.)
- Teak (*Tectona grandis* L.F.)
- Other wood/timber crops

For A23 the following groupings have been made:

Food Crops
Food Crops can be differentiated into **Cereals**, **Fodder** and **Other Food Crops**.

Cereals
Rice (*Oryza sativa*)

Fodder
Water hyacinth (*Eichhornia crassipes*)

Other Food Crops

Non-Food Crops
Non-Food Crops are subdivided into **Biological Filtration**, **Fibre and Structural Material** and **Other Non-Food Crops**. The species are grouped according to their main product being harvested.

Biological Filtration
Water hyacinth (*Eichhornia crassipes*)

Duckweed (*Lemna* spp.)

Bulrush (*Scirpus* spp.)

Reed (*Phragmites* spp.)

Fibre and Structural Material
Reed (*Phragmites* spp.)

Other Non-Food Crops

B15. ARTIFICIAL SURFACES AND ASSOCIATED AREAS

A. SURFACE ASPECT

The surface aspect of areas with an artificial or associated cover is described. Two main classes are distinguished: *built-up areas* and *non built-up areas.*

Built-Up

Built-up areas are characterized by the substitution of the original (semi-)natural cover or water surface by an artificial, often impervious, cover. This artificial cover is characterized usually by a long cover duration.

This class can be subdivided into *linear* and *non-linear* areas.

Linear

This category contains exclusively any transport, communication or supply system that is built as a linear structure (its length is greater than its width) in order to connect two locations. The perimeters of the structure and the material of the cover can be further defined. Subdivision is made into *roads, railways* and *communication lines/pipelines.*

Guideline

This category is typified by natural or artificial materials continuously covering the surface, or the soil surface is modified to such an extent that it can no longer be considered as land. In many cases, these structures form a network that covers the land surface. This surface can consist of hard artificial materials, concrete, gravel or densified soil, or a mixture of any of these materials.

Roads

A more or less uniform material forms a linear structure which covers the land surface over long distances (its length is greater than its width). It is further subdivided into *Paved* and *Unpaved* roads.

Paved roads are covered with an artificial material to consolidate the soil surface, whereas *Unpaved* roads are either bare and consist of a compressed surface, or are covered with unconsolidated material like gravel.

Railways

The land cover consists of a combination of materials (e.g., wood, gravel, concrete, iron) with different permeability to form a very specific linear structure.

Communication Lines/Pipelines

The land cover is characterized by a combination of point-like elements, such as masts, poles, etc., and linear elements. The linear element(s) (e.g., electric wire, pipe) are situated aboveground, supported by the point-like elements. Examples are telephone wires and electric power transmission lines.

Non Linear

This category describes built up areas where non-linear artificial constructions cover the surface and which have an impervious (e.g., concrete, thatch) surface. Subdivision is made into *industrial and/or other areas* and *urban areas.* This subdivision is based on the elements making up this land cover.

Industrial and/or other Areas

Non-linear impervious surfaces are included in this class which are related to trade, manufacturing, distribution and commerce (e.g., airports, ports, factories). The *density* of the artificial constructions in relation to the surrounding area can be described separately.

Urban Area

Urban areas are non-linear built up areas covered by impervious structures adjacent to or connected by streets. This cover is related to centres of population. *Linear* elements like (main) roads, railways and communication lines/pipelines occur but are not a dominant feature. The *density* of the artificial constructions in relation to the surrounding area can be described separately.

Guidelines

This class usually occurs in combination with:

- *Vegetated areas that are connected to buildings that show a regular pattern, such as vegetated courtyards, gardens, etc.*
- *Industrial and/or other areas.*

High/Medium/Low Density

Density is applicable to *Industrial and/or other Areas* and *Urban Areas*. Subdivision is made into the following classes based upon the occurrence of impervious surfaces compared to permeable surfaces:

- High density: more than 75 percent of the total surface consists of impervious surface(s).
- Medium density: 50 to 75 percent of the total surface consists of impervious surface(s).
- Low density: less than 50 percent of the total surface consists of impervious surface(s).

Non Built-Up

This class is defined by absence of the original (semi-) natural cover or water surface.

It is subdivided into:

- *Waste Dump Deposits* in which the existing land or land cover is covered by materials coming from an outside source (artefacts and materials transported by humans).
- *Extraction Sites* in which land cover, rock or earthy materials are removed by human activity or machinery.

The user should note that these areas are considered as "soils" in various soils classification systems (e.g., *Anthrosols* in the FAO Revised Soil Legend (FAO/UNESCO, 1988) and *Anthropogenic Soils*).

A. BUILT-UP OBJECT

This free text field provides the possibility to enter information up to a maximum of 154 characters. A list with a set of standardized options is provided.

- Aerodrome
- Airport
- Breeding Centre
- Cemetery
- Commercial Area (e.g., Shopping)
- Commercial Area (e.g., Warehousing, Wholesaling, Retailing)
- Cultural, Entertainment and Recreation Area
- Heavy Industrial Area (e.g., Ores, Timber, Coal, Chemicals, etc.)
- Historical Site
- Hospital Premises
- Light Industrial Area (Design, Assembly, Finishing, Processing, Packaging of Products)
- Military Facility
- Port Area (including Docks, Shipyards, Locks)
- Power Generation Plant
- Refugee Camp
- Religious Site
- School Premises
- Sewage Treatment Plant
- Sports and Leisure Facilities
- Station (including Depots)
- Transportation Facilities – Bus Area
- Transportation Facilities – Car Park
- Urban Playgrounds (requires Structures)
- Water Treatment Facilities
- Other

BARE AREAS (B16)

A. SURFACE ASPECT

The surface aspect of *Bare Areas* describes the land rather than the land cover because the land is not covered by (semi-)natural or artificial cover. As far as possible, internationally accept guidelines and names have been followed.

The surface aspect of Bare Areas is subdivided into: *Consolidated* and *Unconsolidated* surface

Consolidated

Consolidated bare areas are characterized by the solid and firm consistency of their surface, or by the presence of coarse fragments with these properties. These surfaces are impenetrable with a spade or a hoe. The surface and the coarse materials remain coherent and hard even when moist.

Bare Rock and/or Coarse Fragments

This class contains areas which are either dominated by a continuous rock surface or covered by coarse rock fragments with a subdivision into *Bare Rock* and *Gravel, Stones and Boulders.*

Bare Rock

The rock surface is continuous except perhaps for a few cracks in the material. The remainder of the area may be covered by shallow layers of soil or by isolated pockets of soil or a mixture of both.

Gravel, Stones and Boulders

This class describes areas where rock or mineral fragments cover the surface. The remainder may be covered by shallow soils. Gravel, Stones or Boulders can be specified individually if at least 60 percent of the total coarse fragments consist of any of the three.

The different types of coarse fragments are defined as follow (FAO, 1990):

- Gravel is defined as coarse fragments having a size less than 6 cm.
- Stones are defined as coarse fragments having a size between 6 and 20 cm.
- Boulders are defined as coarse fragments having a size between 20 and 200 cm.

Hardpans

Hardpans are particular soil layers or surfaces that have been indurated due to chemical or physical processes. Their hardness at the surface is irreversible. They form impenetrable layers for water and/or plant roots.

In the context of the Land Cover Classification System, these layers are only described when occurring at the surface.

Ironpan/Laterite

Soils rich in iron are irreversibly hardened. Iron is the "cement" and contains little or no organic matter.

Petrocalcic

The surface of the soil is cemented or indurated by calcium carbonate to the extent that dry fragments do not slake in water and plant roots cannot penetrate.

Petrogypsic

The surface of the soil is cemented or indurated by gypsum to the extent that dry fragments do not slake in water and plant roots cannot penetrate.

Unconsolidated

A defined area is covered with materials that are neither solid nor firm. The surface can be penetrated with a spade or a hoe.

A distinction is made between *Bare Soil and/or other Unconsolidated Material* and *Loose and Shifting Sands.* A *Stony* or *Very Stony* surface can be specified.

Bare Soil and/or Other Unconsolidated Materials

Unconsolidated materials cover the earth's surface, resulting from weathering of parent material (including the effects of moisture and temperature) and/or macro- and micro-organisms. A *Stony* or *Very Stony* surface can be further specified.

Stony

Between 5 and 40 percent of the soil surface is covered with stones. This class can be applied to both *Bare Soil and/or Other Unconsolidated Materials* and *Loose and Shifting Sands.*

Very Stony

Between 40 to 80 percent of the soil surface is covered with stones. This class can only be applied in combination with Bare Soil and/or Other Unconsolidated Materials.

Loose and Shifting Sands

These areas are covered by soil particles. These particles may be moved by regularly occurring winds and form distinct patterns (see Macropattern - Sand). A *Stony* surface can be specified.

B. MACROPATTERN

The Macropattern describes the horizontal pattern/arrangement of a specific surface aspect of soil or sand. This pattern is formed by the elements that form the bare surface (e.g. sand-sand, soil-soil). Therefore, a distinction is made between *Macropattern – Sand* and *Macropattern – Soil.*

Macropattern – Sand: Dunes

Dunes are defined as low ridges or hillocks of drifted sand mainly moved by wind. They occur in deserts or along coasts. The formation of the dunes is dependent on the load of sand, strength and direction of wind, nature of the surface on which sand is moved (sand or rock), presence of an obstacle and the presence of groundwater. Therefore, three types of dunes and two types of occurrence are distinguished:

Barchans

Crescent-shaped sand dunes, lying transversely to the wind direction with the 'horns' trailed downwind.

Parabolic

Elongated dunes with 'horns' pointing upwind.

Longitudinal

Long, narrow, symmetrical dunes running parallel with the prevailing wind direction.

Saturated

The area is covered with clustered dunes. This class can be applied to all three types of dunes.

Unsaturated

The area is covered by dunes occurring in isolation (contrary to the above). This class can be applied to all three types of dunes.

Macropattern – Soil

Termite Mounds

Cone-shaped hills of hardened earth up to several metres high built by termite insects. The termite mounds may be built around tree trunks or poles.

Gilgai

This is the micro-relief typical of Vertisols, which expand and contract largely with distinct seasonal changes in moisture content. Gilgai consists of a succession of enclosed micro-basins and micro-heaps in nearly level areas, or of micro-valleys and micro-ridges that run parallel to the direction of the slope (FAO/UNESCO, 1988).

ARTIFICIAL (B27) AND NATURAL (B28) WATERBODIES, SNOW AND ICE

A. PHYSICAL STATUS

Depending on the physical status of water a distinction is made into *Water, Snow* or *Ice.* These should cover at least 80 percent of the surface of the total area.

Furthermore, it can be specified whether the water or ice is moving or not: Flowing or Standing Water, and Moving or Stationary Ice.

A. PERSISTENCE

The amount and duration of flooding may be dependent on climate and rainfall or controlled by structures like dikes or dams and/or by means of pumps or siphons. A distinction is made into *perennial* and *non-perennial* water persistence. Non-perennial water regimes can be further subdivided according to surface aspect of the land exposed when no water is covering the surface: *bare rock, bare soil* and *sand.*

Perennial

The water covers the surface for more than 9 months each year in all years.

Non-Perennial

The water covers the surface for less than 9 months each year in all years. The surface cover in the absence of water can be further specified.

Tidal (only for B28)

A regular rise and fall in the level of the sea, caused by the attraction of the moon leads to various combinations of water cover and substrate exposure (Cowardin *et al.*, 1979). The four combinations are:

- The substrate is permanently flooded with tidal water (subtidal).
- The land surface is exposed by tides less often than daily (irregularly exposed).
- Tidal water alternately floods and exposes the land surface at least once daily (regularly flooded).
- Tidal water floods the land surface less often than daily (irregularly flooded).

Bare Rock

The substrate surface exposed when water is not persistent. This rock is continuous except for a few cracks. The remainder is covered by shallow layers of soil or sand or by isolated pockets that consist of soil or sand or a mixture of both.

Bare Soil

The substrate surface exposed when water is not persistent.

Bare Sand

The substrate surface exposed when water is not persistent.

B. DEPTH

This class is subdivided into *Deep to Medium Deep* and *Shallow* depth. The classification of Snow and Ice is indicative.

Deep to Medium Deep

The mean water depth during water presence comes to 2 m and more. The lower level of 2 m represents the maximum depth in which rooted emergent water plants can normally grow (Cowardin *et al.*, 1979).

Shallow

The mean water depth is less than 2 m during water presence. The level of 2 m represents the maximum depth in which rooted emergent water plants can normally grow (Cowardin *et al.*, 1979).

C. SEDIMENT LOAD

Sediment load refers to the suspended load in any kind of water system, comprising very fine soil particles which remain in suspension in water for a certain period of time and the coarser sand-sized particles moved by turbulence of the water (Soil Cons. Soc., 1982). Subdivision is made into *Almost No Sediment* and *Sediment.*

Almost No Sediment

The water is clear because sediment concentration is too little to be visible.

Sediment

The sediment concentration is visible, with a concentration ranging from low to high. To classify concentration, data that are defined by the amount of dry sediment per unit volume of water can be applied, giving the following classification (Walling and Webb, 1983):

- Clear to low sediment concentration: less than 300 mg/l.
- Moderate sediment concentration: 300 – 2 000 mg/l.
- High sediment concentration: 2 000 – 6 000 mg/l.
- Very high sediment concentration: more than 6 000 mg/l.

V. SALINITY

Water salinity is described according to the concentration of Total Dissolved Solids (TDS), expressed in part per million (ppm), giving the following classification:

- Fresh: less than 1 000 ppm TDS
- Slightly saline: 1 000 – 3 000 ppm TDS
- Moderately saline: 3 000 – 10 000 ppm TDS
- Very saline: 10 000 – 35 000 ppm TDS
- Brine: more than 35 000 ppm TDS (= water saturated or nearly so with salt).

ENVIRONMENTAL ATTRIBUTES

L. LANDFORM

The landforms refer to the shape of the land surface. Landforms are described primarily by their morphology and not by their genetic origin or by the process responsible for their shape. The dominant slope is the most important differentiating criterion, followed by relief intensity. The SOTER approach (UNEP/ISSS/ISRIC/FAO, 1995) has been adopted at the higher levels.

Level Land

- Plain
- Plateau
- Depression
- Low-Gradient Footslope
- Valley Floor

Sloping Land

- Medium-Gradient Mountain
- Medium-Gradient Hill
- Medium-Gradient Escarpment Zone
- Ridges
- Mountainous Highland
- Dissected Plain

Steep Land

- High-Gradient Mountain
- High-Gradient Hill
- High-Gradient Escarpment Zone
- High-Gradient Valleys

Land With Composite Landforms

- Valley
- Narrow Plateau
- Major Depression

The *topography* refers to the differences in elevation of the land surface on a broad scale. It is derived from the most representative or characteristic slope gradient of the area around, and defined as follows (FAO, 1990):

- Flat to Almost Flat Terrain : 0 - 2 percent
- Gently Undulating to Undulating Terrain: 2 - 10 percent
- Rolling Terrain: 10 - 15 percent
- Hilly Terrain: 15 - 30 percent
- Steeply Dissected to Mountainous Terrain: more than 30 percent

M. LITHOLOGY

The parent material can be identified as well as the age of the geological parent material. Three major groupings are distinguished: *Igneous rock*, *Sedimentary rock* and *Metamorphic rock* (provided by Kroonenberg, 1998).

Geological Parent Materials

Igneous rock
- Igneous plutonic rock
  - Granite
  - Granodiorite
  - Quartz diorite
  - Syenite
  - Monzonite
  - Diorite
  - Gabbro
  - Foidic plutonic rock
  - Ultramafic plutonic rock
- Igneous hypabyssal rock
  - Aplite
  - Pegmatite
  - Porphyry
  - Dolerite/diabase
- Igneous volcanic rock
  - Rhyolite
  - Dacite
  - Trachyte
  - Latite
  - Andesite
  - Basalt
  - Phonolite
  - Tephrite
- Pyroclastic rock
  - Ash
  - Lapilli
  - Scoria
  - Tuff
  - Ignimbrite
  - Lahar
  - Agglomerate
- Other Igneous rock

Sedimentary rock
- Unconsolidated clastic sedimentary rock
  - Clay
  - Silt
  - Sand
  - Gravel
  - Loess
  - Loam
  - Colluvium
  - Shells
- Consolidated clastic siliceous sed. rock
  - Mudstone
  - Siltstone
  - Shale
  - Quartzarenite
  - Lithic arenite
  - Feldspathic arenite/arkose
  - Graywacke
  - Conglomerate
  - Breccia
- Calcareous rock
  - Marl
  - Calcilutite
  - Calcarenite
  - Calcirudite
  - Algal/reefal limestone
  - Travertine
  - Tufa
  - Dolomite
- Evaporite
  - Gypsum
  - Halite
- Organic rock
  - Peat
  - Lignite
  - Coal
  - Tar
- Residual rock
  - Laterite
  - Bauxite
  - Kaolin
- Other Sedimentary rock

Metamorphic rock
- Contact metamorphic rock
  - Hornfels
  - Spotted slate
  - Skarn
- Cataclastic metamorphic rock
  - Cataclastic breccia
  - Mylonite
- Regional-metamorphic rock
  - Slate
  - Schist
  - Gneiss
  - Migmatite
  - Granulite
  - Eclogite
  - Quartzite
  - Marble
  - Serpentinite
- Other Metamorphic rock

The age of the geological parent materials can be specified as follows:

- *Quaternary,* further divided into: Holocene and Pleistocene. The latter is subdivided into: Late Pleistocene, Middle Pleistocene and Early Pleistocene.
- *Tertiary,* further divided into: Pliocene, Miocene, Oligocene, Eocene and Palaeocene.
- *Mesozoic,* further divided into: Cretaceous, Jurassic and Triassic.
- *Palaeozoic,* further divided into: Permian, Carboniferous, Devonian, Silurian, Ordovician and Cambrian.
- *Precambrian.*

N. SOIL – SURFACE ASPECT

The surface aspect of bare areas is described. In contrast to the major land cover type, no distinction is made at this level between *Consolidated* and *Unconsolidated*, but more detailed options are available: *Bare Rock*, *Soil Surface*, *Loose and Shifting Sands* and *Hardpans*.

Bare Rock

The rock surface is continuous except perhaps for a few cracks in the material. The remainder of the area may be covered by shallow layers of soil or by isolated pockets of soil or a mixture of both.

Soil Surface

This class includes the naturally occurring unconsolidated material on the earth's surface, which may result from weathering of parent material, climate (including the effects of moisture and temperature), and macro- and micro-organisms.

Stony

Between 5 and 40 percent of the soil surface is covered with stones. This class can only be applied in combination with *Soil Surface* and *Loose and Shifting Sands*.

Very Stony

Between 40 and 80 percent of the soil surface is covered with stones. This class can be applied with *Soil Surface* and *Loose and Shifting Sands*.

Loose and Shifting Sands

These areas are covered by soil particles between 0.05 mm and 2 mm in diameter. These particles may be moved by regularly occurring winds and form distinct patterns (see *Dunes*).

Stony

Between 5 and 40 percent of the soil surface is covered with stones. This class can only be applied in combination with *Soil Surface* and *Loose and Shifting Sands*.

Very Stony

Between 40 and 80 percent of the soil surface is covered with stones. This class can be applied with *Soil Surface* and *Loose and Shifting Sands*.

Dunes

Dunes are defined as low ridges or hillocks of drifted sand, mainly moved by wind. They occur in deserts or along coasts. The formation of the dunes is dependent on the load of sand, strength and direction of wind, nature of the surface on which sand is moved (sand or rock), presence of any obstacle and the presence of groundwater.

Hardpans

Particular soil layers or surfaces are indurated due to chemical or physical processes. They form impenetrable layers for water and/or plant roots.

Ironpan/Laterite Crust

Soils rich in iron are irreversibly hardened. Iron is the "cement" and these pans contain little or no organic matter. Often, the organic matter is only present in traces.

Petrocalcic

The surface of the soil is cemented or indurated by calcium carbonate to the extent that dry fragments do not slake in water and roots can not penetrate.

Petrogypsic

The surface of the soil is cemented or indurated by gypsum to the extent that dry fragments do not slake in water and roots can not penetrate.

N. SOIL – SOIL PROFILE DESCRIPTION

The soil profile is described and its characteristics. In the classification presented here, the classes followed are as described in the Soil Map of the World – Revised Legend (FAO/UNESCO, 1988).

Histosols

Histosols are formed of incompletely decomposed plant remains. They are characterized by a thick soil horizon that is rich in organic material. These soils formed mainly because of very low temperatures or very wet conditions, or both, throughout the year. Most Histosols are loosely packed in their natural state, and virgin peats retain considerable quantities of water. Histosols are estimated to cover 270 million ha worldwide, mainly in boreal and cold climates, but they also occur in swampy areas throughout the tropical world.

Anthrosols

Anthrosols occur whenever human activities have resulted in profound modifications or burial of the original soils through removal or disturbance of surface horizons, cuts and fills, additions of organic materials, long-continued irrigation, or dumps of waste materials from towns or mines in which soils have developed. These soils are estimated to occupy about 0.5 million ha, mainly in areas of very intensive horticulture and agriculture in Western Europe.

Andosols

Andosols are soils developed in volcanic ash, tuff, pumice and other volcanic ejects of various compositions. The rapid weathering of the porous parent material results in the accumulation of amorphous clays with a high specific surface. In general, Andosols have a fluffy consistency and a dark colour. These soils are further characterized by their high porosity, high permeability and their large soil moisture storage capacity. They are rich in nutrients, but show a great affinity for phosphate ions that they bind and which become unavailable for crops. The total extent of Andosols is estimated at about 110 million ha, concentrated in the circum-Pacific region, corresponding with areas where volcanoes are active.

Arenosols

Arenosols are defined by their sandy particle size and the absence of significant soil profile development. Arenosols are very permeable soils, and their storage capacity for soil moisture is low within the normal rooting depths of crops. Their surface horizon is often pale and poor in organic matter. Their inherent fertility status is low. They are easy to till and tend to form a dry surface quickly, which protects soil moisture against evaporation. For these reasons, they are often preferred over heavier soils for agriculture in semi-arid regions. Arenosols are one of the most extensive soils of the world. They occupy about 900 million ha in the Sahel zone, the Kalahari basin and Australia.

Vertisols

Vertisols are characterized by their high clay contents. They are often dark coloured. Due to their smectite clay mineralogy, they are very hard and crack when dry, but become sticky and plastic (often impassable) when wet. These are chemically rich soils, but they may develop an undulating micro relief (gilgai) which hampers mechanization. Vertisols have great agricultural potential, but special management practices are required to secure sustained agricultural production. Unless mechanization or irrigation is feasible, they are

best suited for grazing. These soils occupy about 340 million ha, mainly concentrated in the Deccan Plateau of India, the Gezira in Sudan, South Africa, Ethiopia, Tanzania, eastern Australia, Argentina and Texas.

Fluvisols

Fluvisols are soils developed in recent fluviatile, lacustrine or marine deposits, particularly in periodically flooded places. They occur in all climates and are mainly associated with great river deltas. Fluvisols receive fresh sediments regularly, show stratified layers and an irregular distribution of organic matter with depth. They are often fertile and occur generally on flat lands. The total area of Fluvisols is estimated at 355 million ha, concentrated in river plains, deltas and coastal lowlands. They are often very productive, except for those on tidal flats that are normally under mangrove in the tropics.

Gleysols

The formation of Gleysols is conditioned by waterlogging at shallow depth for some or all of the year. The prolonged saturation of soils by groundwater in the presence of organic matter results in the reduction of iron, that is partly leached from the soil and forms a grey, olive or blue coloured soil horizon. Subsequent re-oxidation takes place in fissures and brown, yellowish or reddish mottles may appear in the soil.

The total area of Gleysols is estimated at 720 million ha, of which nearly half occurs in Siberia and Alaska. The remainder occurs in the lowland tropics and subtropics, where they are often used for bunded rice growing.

Leptosols

These soils are characterized by their shallow depth over an impermeable layer, rock or ironpan (less than 30 cm). Their limited soil volume makes them subject to drought, but also to waterlogging and runoff. They are the most extensive soil group in the world, with 1 655 million ha, concentrated in mountainous, desert or boreal areas. Most Leptosols remain under their natural vegetation.

Regosols

These soils are characterized by their little soil development due or to the very cold climate in which they occur, or due to steep slopes on which they form in other climates. Surface horizons are often thin and poor in organic matter, and the subsoil reflects the parent material. Their extent is estimated at about 580 million ha.

The land use of Regosols depends mainly on the climate and the relief. Those in the arctic are under natural vegetation, those in warmer and wetter climates can be used for dry farming, but often require supplementary irrigation. Most Regosols remain under natural vegetation.

Cambisols

Cambisols are the second most extensive soils in the world, with an estimated extent of about 1 575 million ha. They are characterized by moderate weathering and an absence of clay immigration. Although their other properties may vary considerably, they generally have good structural stability, a high porosity, good water holding capacity, and good internal drainage. They have a moderate to high natural fertility status and an active soil fauna. They are common in boreal and polar climates, in deserts and mountainous areas.

Ferralsols

Ferralsols are extremely weathered soils developed in a humid or very humid tropical climates. They are characterized by the presence of kaolinitic clays and (hydr)oxides of iron and aluminium, and with a very low content of weatherable minerals. They are deep to very deep and generally show reddish or yellowish colours. Ironstone nodules and ironpans are common. The estimated area of Ferralsols is 745 million ha, mainly concentrated in the areas of tropical rain forests. Ferralsols are very poor in nutrients and the level of aluminium may reach toxic levels in these soils. At the same time, their physical characteristics are favourable. Careful fertilization including liming and phosphorus applications, may make yield reasonably productive soils, particularly for tropical tree crops such as oil palm, coffee and rubber.

Acrisols

Acrisols are soils developed on old land surfaces with a hilly or undulating topography in seasonal dry and humid tropical and monsoon climates. Closed and open woodland is their natural climax vegetation type, often replaced by a tree savannah maintained by seasonal fires. They are characterized by a horizon in which clay has accumulated and by their low base status. They are poor in nutrients and often suffer from aluminium toxicity and phosphorus deficiency. In contrast to the Ferralsols, they are easily eroded and have severe limitations for agriculture. Acrisols cover about 1 000 million ha throughout Southeast Asia, West Africa and the southeastern United States, where they occur with Alisols.

Lixisols

Most Lixisols developed in similar conditions to Acrisols. However, the prevailing present climate is drier and the combined influence of the dry season and the changing vegetation results in a higher nutrient status of these soils. They are characterized by a horizon in which clay has accumulated and by a high base status. These soils are particularly prone to erosion, and they require minimum tillage and conservation measures if brought under agriculture. Lixisols have an estimated extent of 440 million ha, mainly in east central Brazil, the Indian subcontinent and southeast Africa.

Nitisols

Nitisols are characterized by a deep accumulation or clay and a very strong angular blocky structure that shows shiny pressure faces. These soils contain more then 35 percent clay and have a very active soil fauna . They have excellent chemical and physical properties and they are consequently among the most productive soils of the tropics. Their total extent is estimated at 200 million ha, mainly in eastern Africa, the west coast of India, the Philippines, Java, Cuba and Central America.

Plinthisols

Plinthisols develop in tropical conditions and are characterized by the dominant presence of an iron-rich mixture of clay and silica (plinthite) that irreversibly hardens into ironstone concretions and pans on exposure. A groundwater table normally influences these soils. They occupy about 60 million ha, mainly in Brazil and West Africa. Most Plinthisols are poor in nutrients. When the plinthite hardens, the soils suffer from insufficient rooting depths and seasonal dry spells. They are best kept under natural vegetation with associated extensive grazing or fuelwood production. From a civil engineering point of view, plinthite is a good material to make building blocks.

Alisols

These are characterized by a mixed clay mineralogy, clay migration and a very low base status. They are very acid and have generally a very high aluminium content.

The physical characteristics are also unfavourable: a low structural stability of the surface horizon results in slaking and a reduced permeability and internal drainage.

Their extent is unknown, but probably about 100 million ha, mainly in the tropics and subtropics, but they may occur under forest in more temperate and colder climates.

Liming and fertilizer application may overcome their low chemical fertility, while minimum tillage helps to preserve the surface soil.

Solonchaks

Solonchaks are saline soils formed when evaporation greatly exceeds evaporation as in arid and semi-arid areas, or where salts are present in the parent material of the soil.

Solonchaks cover about 190 million ha, with vast areas occurring in Chad, Namibia and Australia, along the Gulf, in Paraguay and Uruguay.

The high salt content limits plant growth to salt tolerant plants and halophytes. Solonchaks can not be used for agriculture unless an excess of irrigation water leaches the salts out, while a drainage system that keeps the groundwater table at sufficient depth is often required.

Solonetz

Solonetz are formed in environments with a pronounced dry season and where sodium is present in excess over calcium, due to saline groundwater, or sodium-containing minerals in the parent material. Clay is dispersed and forms a dense accumulation horizon at shallow depth with a typical columnar or prismatic soil structure.

The extent of these soils is estimated at about 135 million ha in the same areas where Solonchaks occur, but they are also important in colder climates with a pronounced dry season, such as Canada and the former Soviet Union.

The high sodium content directly affects plant growth. Most Solonetz are used for extensive grazing, but they can be reclaimed in colder climates through deep ripping, irrigation with calcium-rich water, and pyrite or gypsum applications.

Gypsisols

In arid regions, Gypsisols form through dissolution from calcium sulphate contained in weathering materials and precipitation of gypsum in the subsoil as a fine white powder, crystals, pebbles, stones or even at the surface of the soil as desert roses. If sufficiently abundant, a hard gypsum crust may be formed.

The total extent of Gypsisols is estimated at about 90 million ha, mainly concentrated in the driest part of the arid climatic zone: the Libyan and Namibian deserts, Yemen, Somalia, northern Iraq and Syria.

Chemical fertility of these soils is low and their physical characteristics unfavourable. With irrigation, drainage and heavy fertilization, good yields may be obtained for alfalfa, wheat, apricots and grapes.

Calcisols

The most prominent feature of Calcisols is the translocation of calcium carbonate from the surface layers to an accumulation layer at some depth in the soil. This layer may be soft and powdery, or consists of hard concretions and can eventually become indurated and cemented.

The extent of Calcisols is estimated at about 800 million ha, mainly concentrated in semi-arid and Mediterranean climates.

Most Calcisols have a medium to fine texture and a good water holding capacity. They are generally well drained. These are potentially fertile soils, but their high calcium carbonate content is not favourable for many crops and may result in iron and zinc deficiency in crops. These soils are mainly used for grazing.

Chernozems

In the colder areas of steppe climates, Chernozems develop, which are soils with a very dark, deep, humus- and nutrient-rich topsoil. These soils may contain 4 to 16 percent of organic matter and show an intense activity of earthworms and other small burrowing animals.

Chernozems cover about 230 million ha worldwide, mainly in Eurasia and North America. The chemical and physical properties of these soils are very favourable for agriculture.

Kastanozems

In the dry and warmer areas of the steppe region the natural vegetation is dominated by early ripening grasses resulting in Kastanozems with a brown soil surface horizon, rich in organic matter (2 to 4 percent) and characterized by an accumulation of calcium carbonate (or even gypsum) in the subsoil.

Kastanozems have an estimated extent of 465 million ha, mainly concentrated in areas bordering deserts: the southern republics of the former Soviet Union, central Mongolia, northern Argentina and Paraguay, and throughout north and central America.

The physical characteristics of Kastanozems are slightly less favourable than those of the Chernozems, but otherwise these soil groups are comparable.

Greyzems

In the narrow belt north of the zone of the Chernozems, the climate favourable for a steppe-like vegetation no longer exists and deciduous forests have invaded former grasslands. The characteristic nutrient- and humus-rich surface horizon of the steppe soils still persists however .Greyzems are further characterized by clay accumulation and the occurrence of bleached sand and silt particles in the surface horizon.

Most Greyzems are well drained, have a good soil moisture storage capacity and a good chemical fertility. They may suffer from dry and from wet spells and from surface crusting.

Normally they remain under forest but they can be used for cryophylic cereals and spring-grown crops.

Phaeozems

Phaeozems occur in more humid and warmer environments than other steppe soils and their weathering and leaching are more pronounced. Phaeozems are characterized by their

humus-rich surface horizon and the absence of calcium carbonate accumulations in the subsoil.

Phaeozems are estimated at about 155 million ha, mainly in the North American prairie region, the pampas of Argentina and Uruguay and the subtropical steppe of Eastern Asia.

Phaeozems are porous, well aerated soils with stable structures, relatively rich in nutrients and make excellent farmland.

Luvisols

These soils are characterized by clay migration from the surface horizon to an accumulation horizon at some depth, and a rich nutrient status. They are common in flat or gently sloping land in cool temperate climates and in Mediterranean zones with a distinct dry and wet season.

Luvisols cover about 650 million ha in west-central Russia, the USA and Central Europe. In warmer regions, they are common in the Mediterranean basin and in southern Australia.

Luvisols are in general fertile soils with a high nutrient content and moderate to high soil moisture storage capacity. Luvisols are often intensively used for agriculture.

Podzoluvisols

Podzoluvisols are characterized by a distinct bleached, iron- and clay-depleted horizon overlying and penetrating into a brownish horizon of clay accumulation. They have developed in flat and undulating landscapes previously covered by ice. Their natural vegetation is taiga or coniferous and mixed forest.

Podzoluvisols cover about 320 million ha, mainly concentrated in a broad belt extending from Poland to western Russia, and eastward into central Siberia, and in central Canada extending westward from Baffin Bay.

Most of the Podzoluvisols are acid, have a low nutrient content and their structure is easily destroyed. Many of these soils remain under natural forest vegetation.

Podzols

Podzols are characterized by a horizon in which iron and aluminium, or organic matter, or both, have accumulated. Normally this layer underlies a bleached horizon.

The topsoil of Podzols shows little biological activity. In the Northern Hemisphere, Podzols occur generally in boreal and cold climates under heather or coniferous forest. In the humid tropics they occur exclusively in sandy materials and are under open forest or savannah.

Podzols occupy about 400 million ha worldwide, mainly concentrated in Scandinavia, Russia, and Canada south of Baffin Bay. Tropical Podzols occur along the Rio Negro, in the Guineas, in northern Australia, in Indonesia and in western Zambia.

Podzols are chemically poor and may suffer from waterlogging. They are normally left under their natural vegetation.

Planosols

These soils are characterized by a coarse-textured layer abruptly overlying a deeper horizon with considerably more clay. Planosols mainly occur in water-receiving sites on flat or gently undulating terrain, with a natural vegetation of grasses or open forest.

Planosols worldwide cover about 130 million ha, with important concentrations in Brazil, northern Argentina, South Africa and eastern Australia.

Chemical properties of Planosols are variable, but they generally have a moderate to low fertility level. They have low structural stability and, due to the compactness of the subsoil, they often suffer from seasonal waterlogging. They are difficult to manage or improve, and are often used for extensive grazing.

O. CLIMATE

The climate is classified according to the Agro-Ecological Zoning methodology as developed by FAO (De Pauw *et al.,* 1995). Two items need to be determined: the *Thermal Climate* and the *Length of Growing Period* (LGP).

Thermal Climate

1. *Tropics* Monthly mean temperature (T_{mean}) more than12° to18 ℃ in every month.

2. *Subtropics – Summer Rainfall* (T_{mean}) in every month more than 5 ℃ and at least one month with T_{mean} less than 18 ℃.

Precipitation (P) concentrated in summer (P_{summer} more than P_{winter}).

3. *Subtropics – Winter rainfall* As for 2, but P_{winter} more than P_{summer}.

4. *Temperate Oceanic* Four or more months have T_{mean} more than 10 ℃ and at least one month has T_{mean} less than 5 ℃. The difference between the T_{mean} of warmest and coldest month is less than 20 ℃.

5. *Temperate Continental* As for 4, but the difference between T_{mean} warmest and coldest is more than 20 ℃.

6. *Boreal Oceanic* One to four months have T_{mean} more than 10°C and at least one month has T_{mean} less than 5 ℃. Difference in T_{mean} between warmest and coldest month is less than 20 ℃.

7. *Boreal continental* As for 6 but difference in T_{mean} between warmest and coldest months is more than 20 ℃.

8. *Polar/Arctic* All months have a T_{mean} less than 10 ℃.

Temperature and Moisture-Delimited Length of Growing Period (LGP)

This is the period of the year that moisture and temperature are not inhibiting crop growth. In technical terms, it is calculated as the period starting when rainfall is more than 0.5 Potential Evapotranspiration (PET) or T_{mean} is bigger than 5°C, whichever comes last, and ends when a maximum soil moisture storage of 100 mm has been depleted or rainfall is less than 0.5 PET or T_{mean} is less than 5°C, whichever comes first. The growing period can be broken by a dormancy period. Killing temperatures, snow cover and a soil moisture depletion factor are all taken into account in the calculation.

The following classes are suggested:

- Hyperarid: LGP = 0 days
- Arid: LGP = 1 – 59 days
- Dry Semi-Arid: LGP = 60 – 119 days
- Moist Semi-Arid: LGP = 120 – 179 days
- Subhumid: LGP = 180 – 239 days
- Humid: LGP = 240 – 329 days
- Perhumid: LGP more than 330 days

P. ALTITUDE

The following altitude ranges, based on their ecological meaning, are distinguished:

1. **Less than 50 - 300 m**. This altitude range is further subdivided into:

   less than 50 m

   50 – 100 m

   100 – 300 m

2. **300 - 1 500 m**. This altitude range is further subdivided into:

   300 – 600 m

   600 – 1 000 m

   1 000 – 1 500 m

3. **1 500 - 3 000 m**. This altitude range is further subdivided into:

   1 500 – 2 000 m

   2 000 – 2 500 m

   2 500 – 3 000 m

4. **3 000 to more than 5 000 m**. This altitude range is further subdivided into:

   3 000 – 3 500 m

   3 500 – 5 000 m

   more than 5 000 m

Q. EROSION

No Visible Erosion

No visible traces of erosion can be recognized on the surface.

Visible Evidence of Erosion

Visible traces of erosion can be recognized on the surface but are not further specified. A further distinction can be made into *Water Erosion, Wind Erosion* and *Mass Movement.*

Water Erosion

Raindrop erosion or splash erosion, the result from the impact of water drops directly on the soil particles, is the initial step in all water erosion. The transport of soil particles by water either in sheet, rill or gully erosion is defined below.

Sheet Erosion

In the classic concept, sheet erosion was defined as the uniform removal of soil in thin layers from sloping land, resulting in sheet or overland flow in thin layers. However, studies have revealed that minute rilling take place almost simultaneously with the first detachment and movement of soil particles (Hudson, 1981; Schwab *et al.*, 1981). The constant change of position of these tiny rills obscure their presence from normal observation. Raindrops cause soil particles to be detached and the increased sediment load reduces the infiltration rate by sealing the soil pores. The soil particles are subsequently transported by runoff.

Guideline

During development of sheet erosion, pedestals may be formed, boulders may be left with a soil "collar," roots of trees may get exposed, or subsurface soil horizons may appear at the surface.

Rill Erosion

Rill erosion is the removal of soil by water from small but well-defined channels or streamlets when there is a concentration of overland flow. Rills are defined as less than 30 cm deep and they are small enough to be easily removed by normal tillage operations. They disappear normally after proper land preparation (e.g., ploughing) and are no longer mappable.

Gully Erosion

Gully erosion is the removal of soil by water from channels larger than rills. These channels carry water during and immediately after rains, and unlike rills, gullies can not be removed by tillage operations. A gully develops by processes that take place either simultaneously or during different periods of its growth:

- waterfall erosion at the gully head;
- channel erosion by water flow through the gully with raindrop splash on unprotected soil; and
- mass movement (collapse or slump from the sides) of soil in the gully.

Wind Erosion

Soil movement is initiated as a result of turbulence and velocity of wind. The sediment is transported in suspension, by saltation or creep. The quantity of soil moved is influenced by the particle size, gradation of particles, wind velocity and distance across the eroding area. The rate of movement increases with distance from the windward edge of the field or

eroded area. These increased rates of soil movement with distance from the windward edge of the area subject to erosion are the result of increasing amounts of erosive particles, thus causing greater abrasion and a gradual decrease in surface roughness. The rate of erosion varies for different soils. Deposition of sediment occurs when gravitational force is greater than the forces holding the particles in the air. This usually occurs when there is a decrease in wind velocity caused by vegetation or other physical barriers.

Mass Movement

Masses of locally saturated soil move downhill, usually in one single movement before coming to rest. This type of erosion usually occurs after protracted rains. Although quite large quantities of soil may be moved, there is relatively little disturbance within this soil mass. A small crescent shaped slip scar is formed where the faster moving downslope soil tears away from the slower moving upslope soil.

R. WATER QUALITY

Depending on the level of Total Dissolved Solids (TDS) expresses in part per million (ppm), three classes are distinguished: fresh, brackish and saline water (Cowardin *et al.*, 1979).

- Fresh Water: Less than 1 000 ppm TDS.
- Brackish Water: Between 1 000 – 10 000 ppm TDS.
- Saline Water: More than 10 000 ppm TDS.

U. SCATTERED VEGETATION

Scattered Vegetation Present

In areas with less than 4 percent vegetative cover, some vegetation may be present and usually this vegetation is scattered over the whole area. The life forms composing this type of vegetation can be any life form and, due to their scattered distribution, it may be difficult to further specify them.

Woody

Perennial plants with stem(s) and branches from which buds and shoots develop (Ford-Robertson, 1971). Semi-woody plants are included here (Eiten, 1968).

Guidelines

The life forms composing Woody *vegetation can be trees or shrubs but, due to their scattered distribution, it may be difficult to distinguish one from the other.*

Herbaceous

Plants without persistent stem or shoots above ground and lacking definite firm structure (Scoggan, 1978). There are two categories depending on the physiognomy (Kuechler and Zonneveld, 1988; UNESCO, 1973): *Forbs* and *Graminoids.*

Guidelines

The life forms composing Herbaceous *vegetation can be* Forbs *or* Graminoids, *but, due to their scattered distribution, it may be difficult to distinguish one from the other.*

Forbs

All broad-leaved herbaceous plants in the common sense (e.g., sunflower, clover, etc.) and all non-graminoid herbaceous plants (UNESCO, 1973). Therefore ferns, except tree ferns (Kuechler and Zonneveld, 1988) and very low non-leafy succulents (Eiten, 1968) are included.

Guideline

This subdivision can only be applied if Forbs *comprise more than 75 percent of the herbaceous coverage.*

Graminoids

All herbaceous grasses and other narrowleaved grass-like plants that are not grasses according to the taxonomic definition (Kuechler and Zonneveld, 1988). Bamboos are also grasses but they are woody and therefore classed with shrubs or trees.

Guidelines

This subdivision can only be applied if Graminoids *comprise more than 75 percent of the herbaceous coverage.*

Lichens/Mosses

Lichens are composite organisms formed from the symbiotic association of fungi and algae. They encrust rocks, tree trunks, etc., and are often found under extreme environmental conditions (Lawrence, 1989). In tundras of North America and Eurasia, lichens (e.g., *Cladonia* spp.) may cover large areas (Kuechler and Zonneveld, 1988).

Mosses are a group of photo-autotrophic land plants without true leaves, stems, roots, but with leaf- and stemlike organs (e.g., sphagnum) (Gray, 1970). Several plants commonly called mosses belong to other groups: reindeer moss is a lichen; Spanish moss is a vascular plant (parasite); Irish moss is an algae (Lawrence, 1989).

Guidelines

This category is only applied if the other life forms are not present and when Lichen/Mosses *cover is more than 4 percent but less than 20 percent. Otherwise they do not form a specific class, but their presence can be mentioned in the description of another land cover class.*

Lichens *is only applied when both lichens and mosses are present but* Lichens *comprise more than 75 percent of the total cover.*

Mosses *is only applied when both lichens and mosses are present but* Mosses *comprise more than 75 percent of the total cover.*

W. CROP COVER/DENSITY

The *Crop Cover/Crop Density* can be considered as the proportion of a particular area of the ground or substrate covered by a layer of plants considered at the greatest horizontal perimeter level of each plant in the layer (according to Eiten, 1968). A distinction is made for *Permanent Life Forms* into *Closed* (more than 60-70 percent), *Open* ((70-60 percent) to (20-10 percent)) and *Sparse* (less than 20-10 percent), and for *Temporary Life Forms* into.*High* (more than 60 percent), *Medium* (60 - 30 percent) and *Low* (30-15 percent) The reason for expressing the *Crop Cover/Crop Density* through ranges instead of using absolute values will be described under the respective guidelines. As herbaceous plants are seasonal in character, it has to be stressed that the cover of herbaceous vegetation is always considered at the time of its fullest development.

In addition to specification of the Crop Cover/Density, the user can add to the land cover class of *Permanent Life Forms* the attribute *Plantation* or *Orchard*. In practice, many tree or shrub crops are described in those terms (e.g. rubber plantation, tea plantation) and that is the reason why they have been included.

Permanent Life Forms (e.g., Trees and Shrubs)

Closed (>(70-60) percent)

A layer of a certain Permanent Life Form covers more than 60-70 percent of a defined area. The crowns interlock, touch or are very slightly separated. In the latter case the distance between two perimeters is at least 1/6 of the crown average diameter (Eiten, 1968). The crowns can form an even or uneven closed canopy layer.

Guideline

If plants are growing in a defined area with the crowns being tangent to each other, presuming that the crowns of a woody Life Form are round, the cover of the canopy will be approximately 78 percent. As crowns are in reality interlocking and small open space of the canopy are frequent in a closed canopy layer, the lower limit of closed vegetation is set at 60 percent. Because of the great variability of the horizontal character of closed vegetation, namely different crown shapes of the plant species, the value range can vary from 60 to 70 percent.

Open ((70-60) – (20-10) percent)

Between 70-60 percent and 20-10 percent of a defined area is covered by a certain layer of a Permanent Life Form. The crowns are usually not interlocking. The distance between the perimeters can range from very slightly more than the average diameter, up to twice the average diameter (Eiten, 1968).

Guideline

In the case of woody vegetation with a cover of (70-60) -40 percent, the plants are standing rather close together and from a distance, they may appear to grow continuously (Kuechler and Zonneveld, 1988).

Sparse (20-10 percent)

A certain layer of Permanent Life Forms covers (20-10) percent of a defined area. The distance between two perimeters of a Life Form is more than twice the average perimeter diameter (Eiten, 1968). In many cases, a sparse Life Form might be associated with another Life Form of greater cover continuity (e.g., a young rubber tree plantation with graminoids).

Guidelines

The range of 20 to 10 percent is applied because sparse cover is rarely homogenous and therefore cannot be easily defined as one single value. Please note the difference in the lower threshold value compared to Natural and Semi-Natural Terrestrial Vegetation *(A12).*

Temporary Life Forms (e.g., Herbaceous)

For Temporary Life Forms the Crop Density can be described. This cover information will inform the user of a possible crop failure. Description of the Crop Density for seasonal plants should take place at the time of its fullest development.

High (> 60 percent)

A certain layer of a Temporary Life Form covers more than 60 percent of a defined area.

Medium (60 – 30 percent)

A certain layer of a Temporary Life Form covers between 60 and 30 percent of a defined area.

Low (30 – 15 percent)

A certain layer of a Temporary Life Form covers between 30 and 15 percent of a defined area.

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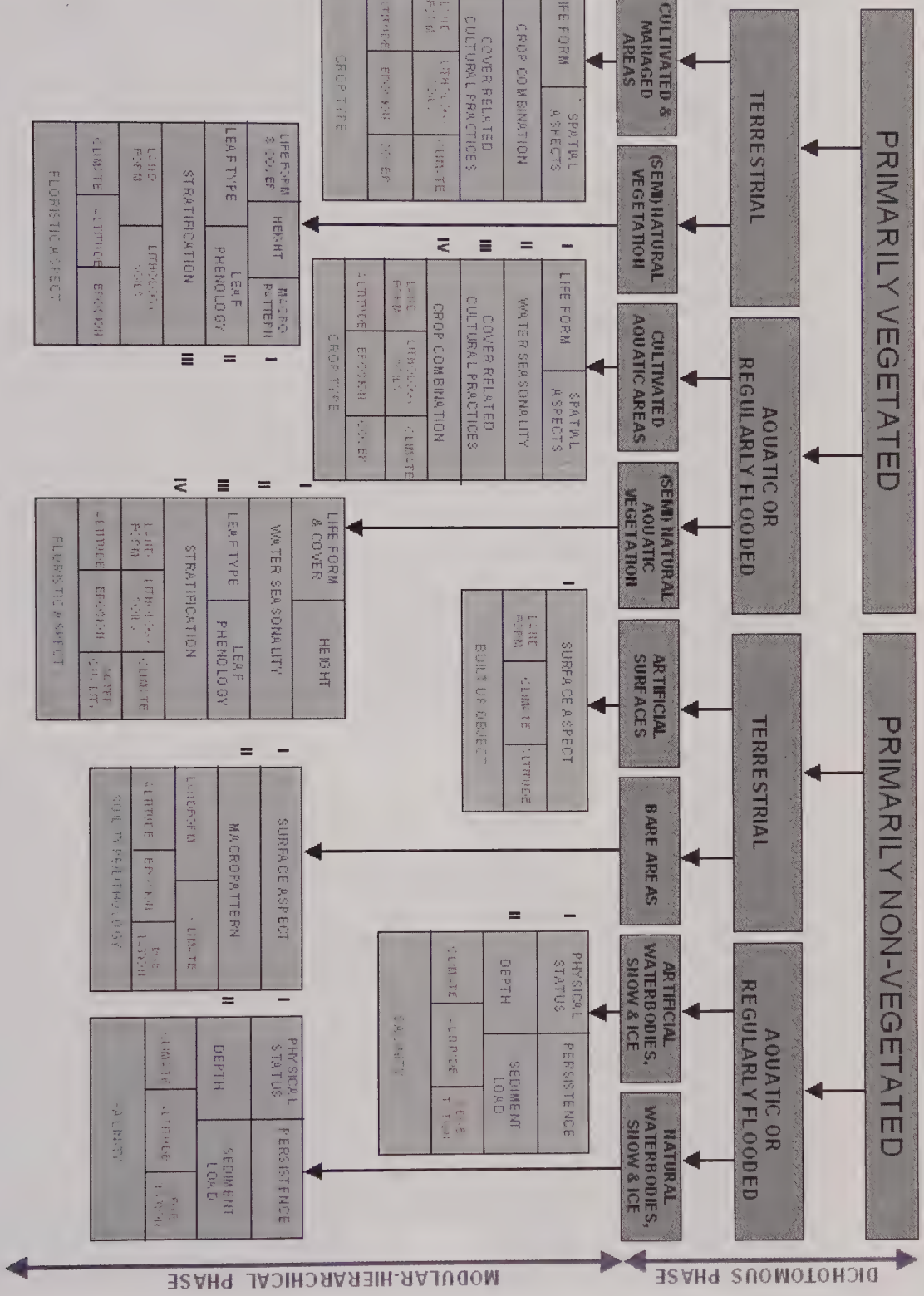
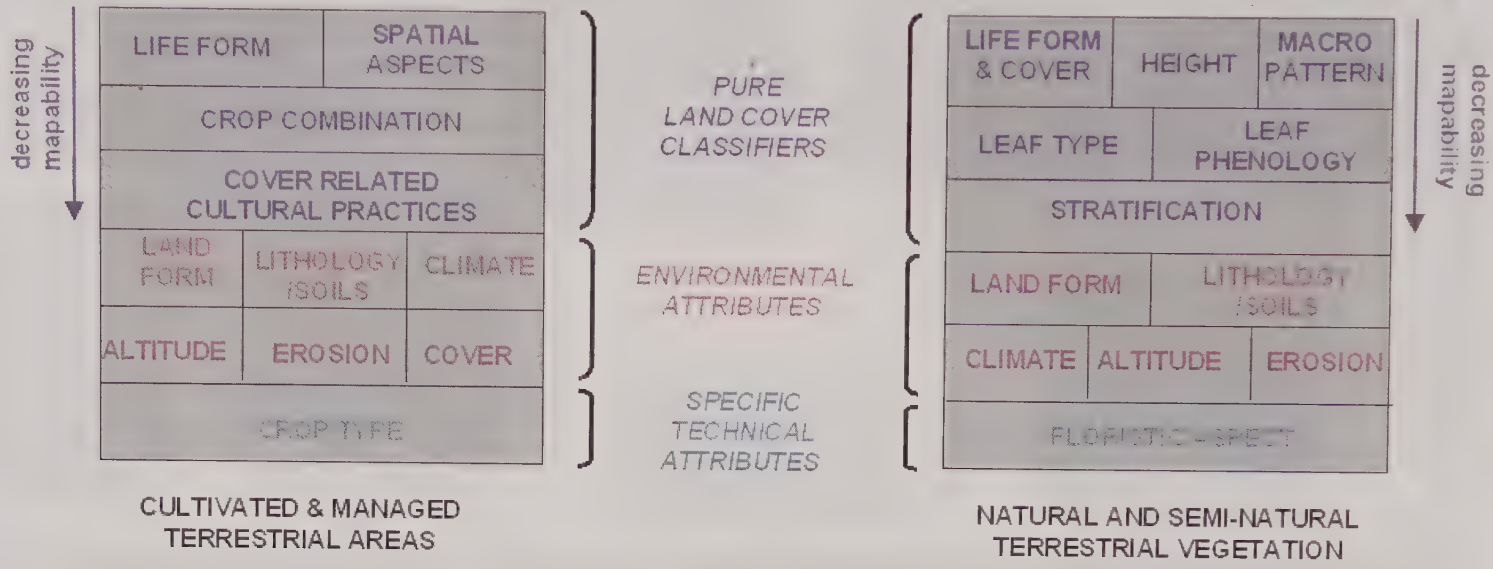
APPENDIX B.

PRESENTATION OF MAJOR LAND COVER CATEGORIES


PRIMARILY VEGETATED
PRIMARILY NON-VEGETATED
TERRESTRIAL
AQUATIC OR REGULARLY FLOODED
TERRESTRIAL
AQUATIC OR REGULARLY FLOODED
CULTIVATED & MANAGED AREAS
(SEMI) NATURAL VEGETATION
CULTIVATED AQUATIC AREAS
(SEMI) NATURAL AQUATIC VEGETATION
ARTIFICIAL SURFACES
BARE AREAS
ARTIFICIAL WATERBODIES, SNOW & ICE
NATURAL WATERBODIES, SNOW & ICE
LIFE FORM
SPATIAL ASPECTS
CROP COMBINATION
COVER RELATED CULTURAL PRACTICES
CROP TYPE
WATER SEASONALITY
LIFE FORM & COVER
HEIGHT
LEAF TYPE
LEAF PHENOLOGY
STRATIFICATION
SURFACE ASPECT
BUILT UP OBJECT
MACROPATTERN
PHYSICAL STATUS
PERSISTENCE
DEPTH
SEDIMENT LOAD
DICHOTOMOUS PHASE
MODULAR-HIERARCHICAL PHASE

MODULAR-HIERARCHICAL PHASE

THE HIERARCHICAL ARRANGEMENT OF THE LAND COVER CLASSIFIERS ASSURES A HIGH *MAPABILITY*, THAT IS GEOGRAPHIC ACCURACY, AT THE HIGHEST LEVELS OF THE CLASSIFICATION.

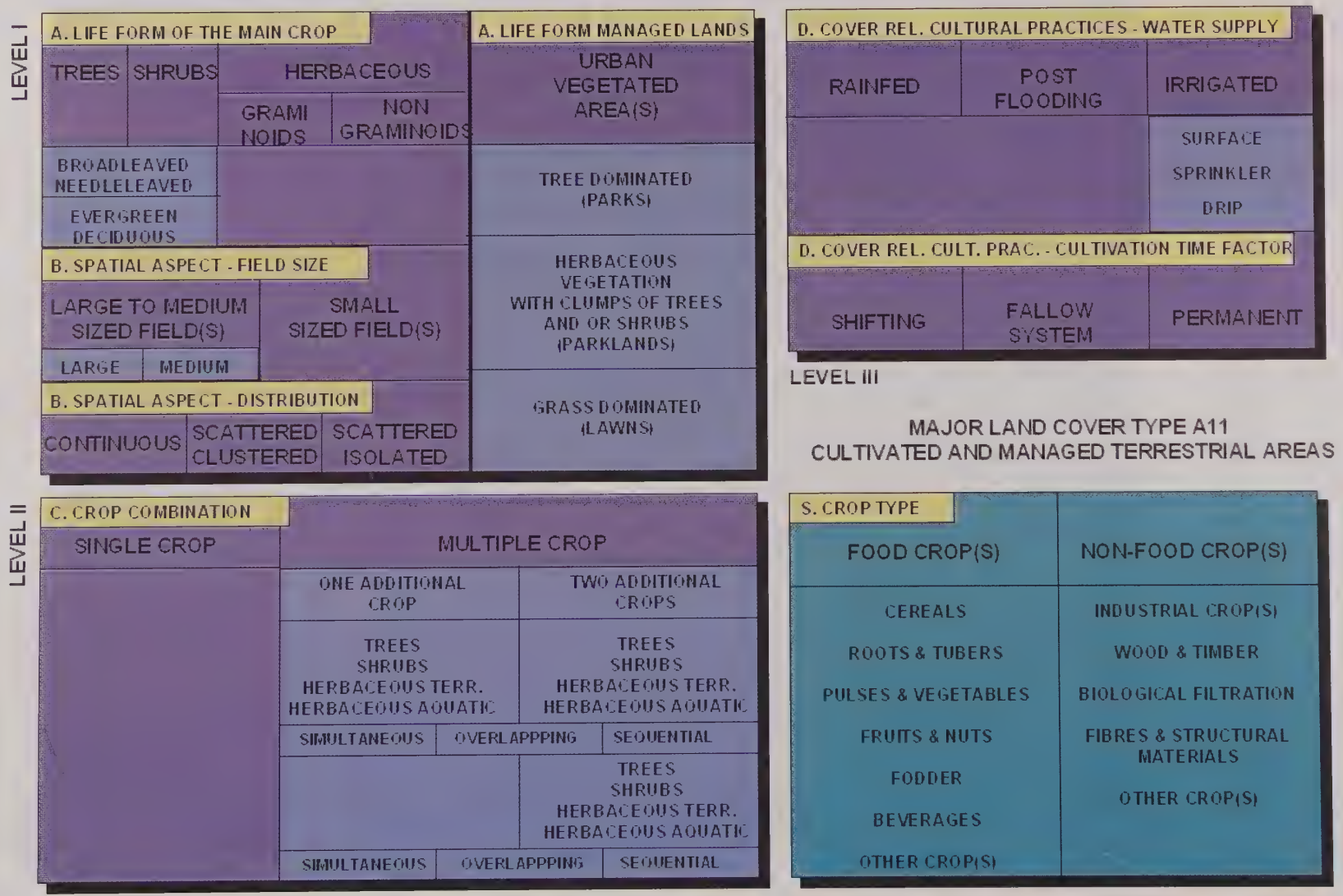


CULTIVATED & MANAGED TERRESTRIAL AREAS

NATURAL AND SEMI-NATURAL TERRESTRIAL VEGETATION

A LAND COVER CLASS IS THUS DEFINED BY:

1. THE STRING OF CLASSIFIERS USED (ALL CLASSIFIERS ARE CODED):
2. A STANDARDIZED DESCRIPTIVE NAME:
3. A UNIQUE NUMERICAL CODE FOR USE IN GEOGRAPHIC INFORMATION SYSTEMS.



MAJOR LAND COVER TYPE A11
CULTIVATED AND MANAGED TERRESTRIAL AREAS

LEVEL I

- A. LIFE FORM OF MAIN LAYER
  - WOODY
    - TREES
    - SHRUBS
  - HERBACEOUS
    - FORBS
    - GRAMINOIDS
  - LICHENS/MOSSES
    - LICHENS
    - MOSSES
- A. COVER OF MAIN LAYER
  - CLOSED > (70-60) %
  - OPEN (70-60) - (20-10) %
  - (70-60) - 40 %
  - 40 - (20-10) %
  - SPARSE (20-10) 1 %
  - SPARSE (20-10) - 4 %
  - SCATTERED * 4-1 %
- B. HEIGHT
  - 7 - 2 m (only for WOODY)
  - 3 - 0.03 m
  - > 30 - 3 m
  - 5 - 0.3 m
  - > 14 m
  - 5 - 0.5 m
  - 3 - 0.3 m
  - 14 - 7 m
  - 5 - 3 m
  - 3 - 0.5 m
  - 3 - 0.8 m
  - 0.8 - 0.3 m
  - 7 - 3 m
  - < 0.5 m
  - 0.3 - 0.03 m
- C. SPATIAL DISTRIBUTION - MACROPATTERN
  - CONTINUOUS
  - FRAGMENTED
    - STRIPED
    - CELLULAR
  - PARKLIKE PATCHES

LEVEL II

- D. LEAF TYPE
  - BROADLEAVED
  - NEEDLELEAVED
  - APHYLLOUS
- D. LEAF PHENOLOGY
  - EVERGREEN
  - DECIDUOUS
  - MIXED (BROADLEAVED DECIDUOUS WITH NEEDLELEAVED EVERGREEN)
  - SEMI-DECIDUOUS OR SEMI-EVERGREEN (BROADLEAVED EVERGREEN & DECIDUOUS)
  - MIXED (FOR FORBS & GRAMINOIDS)
  - PERENNIALS
  - ANNUALS

LEVEL III

- F. STRATIFICATION
  - SECOND LAYER AND/OR THIRD LAYER: ABSENT
    - WOODY
      - TREES
      - SHRUBS
    - HERBACEOUS
  - PRESENT
- F. COVER
  - CLOSED TO OPEN
  - CLOSED (> 70 - 60) %
  - OPEN (70 - 60) - (20 - 10) %
  - SPARSE (20-10) - 5 %
- G. HEIGHT
  - > 30 - 0.3 m (only for WOODY)
    - > 30 - 3 m
    - > 14 m
    - 14 - 7 m
    - 7 - 3 m
    - 5 - 0.3 m
    - 5 - 3 m
    - 3 - 0.5 m
    - < 0.5 m
  - 3 - 0.03 m
    - 3 - 0.3 m
    - 0.3 - 0.03 m

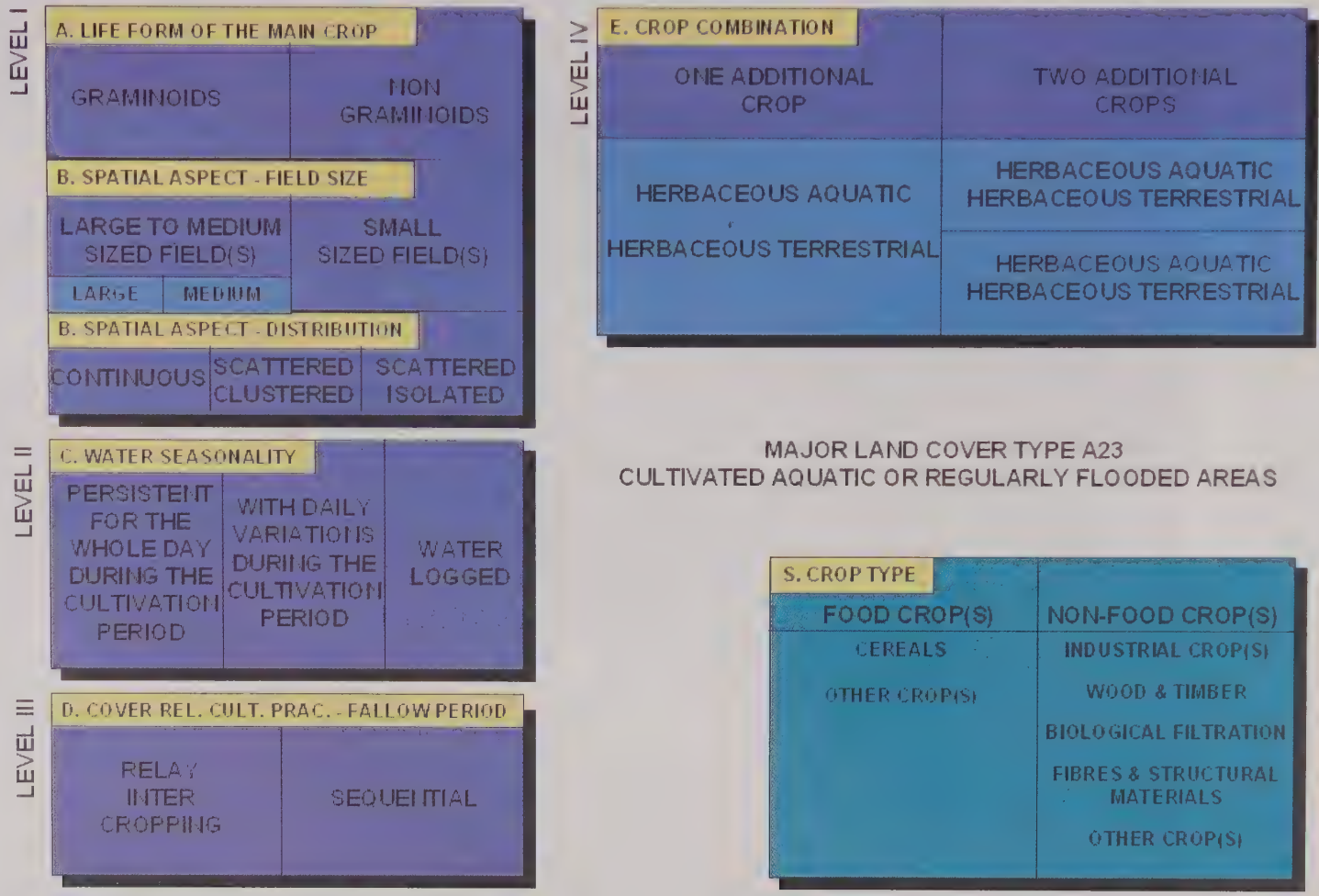
MAJOR LAND COVER TYPE A12
NATURAL AND SEMI-NATURAL TERRESTRIAL VEGETATION

***SCATTERED**

This classifier is only applicable if the total cover of all vegetation in the area is more than 4 percent.

SPECIFIC TECHNICAL ATTRIBUTE OF MAJOR LAND COVER TYPES A12 AND A24

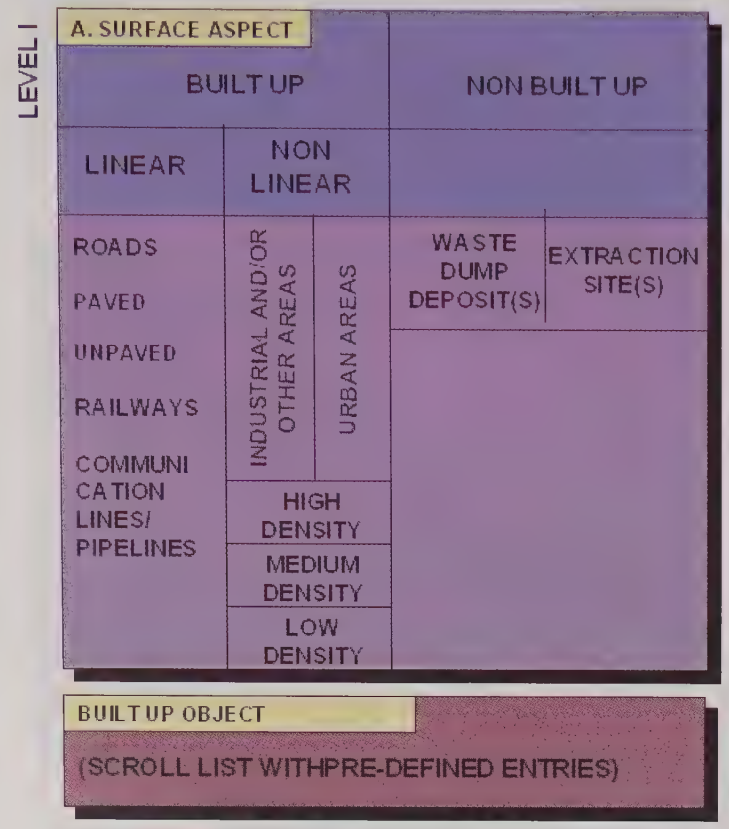
T. FLORISTIC ASPECT			
SINGLE PLANT SPECIES		GROUPS OF PLANT SPECIES	
DOMINANT SPECIES (HEIGHT, COVER OR COMBINATION OF BOTH)	MOST FREQUENT SPECIES	STATISTICALLY DERIVED PLANT GROUPS	PLANT GROUPS DERIVED WITHOUT USING STATISTICAL METHODS (SAME ECOLOGICAL SIGNIFICANCE, SAME GEOGRAPHIC DISTRIBUTION, SAME DYNAMIC SIGNIFICANCE)


LEVEL I
A. LIFE FORM OF THE MAIN CROP
GRAMINOIDS
NON GRAMINOIDS
B. SPATIAL ASPECT - FIELD SIZE
LARGE TO MEDIUM SIZED FIELD(S)
SMALL SIZED FIELD(S)
LARGE
MEDIUM
B. SPATIAL ASPECT - DISTRIBUTION
CONTINUOUS
SCATTERED CLUSTERED
SCATTERED ISOLATED
LEVEL II
C. WATER SEASONALITY
PERSISTENT FOR THE WHOLE DAY DURING THE CULTIVATION PERIOD
WITH DAILY VARIATIONS DURING THE CULTIVATION PERIOD
WATER LOGGED
LEVEL III
D. COVER REL. CULT. PRAC. - FALLOW PERIOD
RELAY INTER CROPPING
SEQUENTIAL
LEVEL IV
E. CROP COMBINATION
ONE ADDITIONAL CROP
TWO ADDITIONAL CROPS
HERBACEOUS AQUATIC
HERBACEOUS TERRESTRIAL
HERBACEOUS AQUATIC HERBACEOUS TERRESTRIAL
HERBACEOUS AQUATIC HERBACEOUS TERRESTRIAL
MAJOR LAND COVER TYPE A23
CULTIVATED AQUATIC OR REGULARLY FLOODED AREAS
S. CROP TYPE
FOOD CROP(S)
NON-FOOD CROP(S)
CEREALS
OTHER CROP(S)
INDUSTRIAL CROP(S)
WOOD & TIMBER
BIOLOGICAL FILTRATION
FIBRES & STRUCTURAL MATERIALS
OTHER CROP(S)

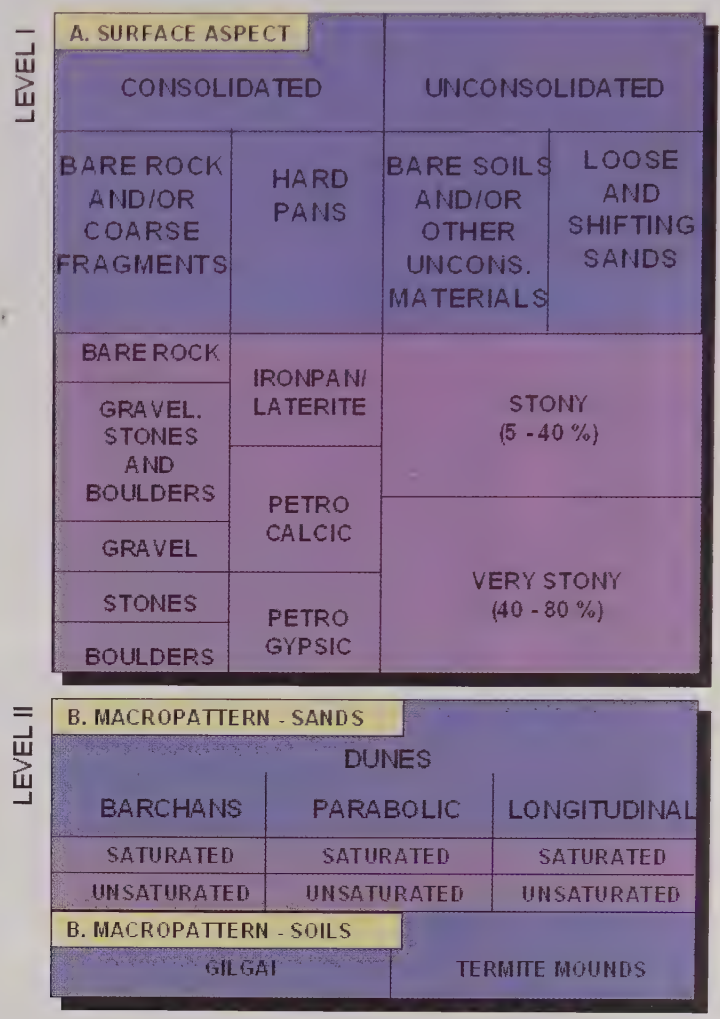
MAJOR LAND COVER TYPE A24
NATURAL AND SEMI-NATURAL
AQUATIC OR REGULARLY FLOODED VEGETATION

'SCATTERED

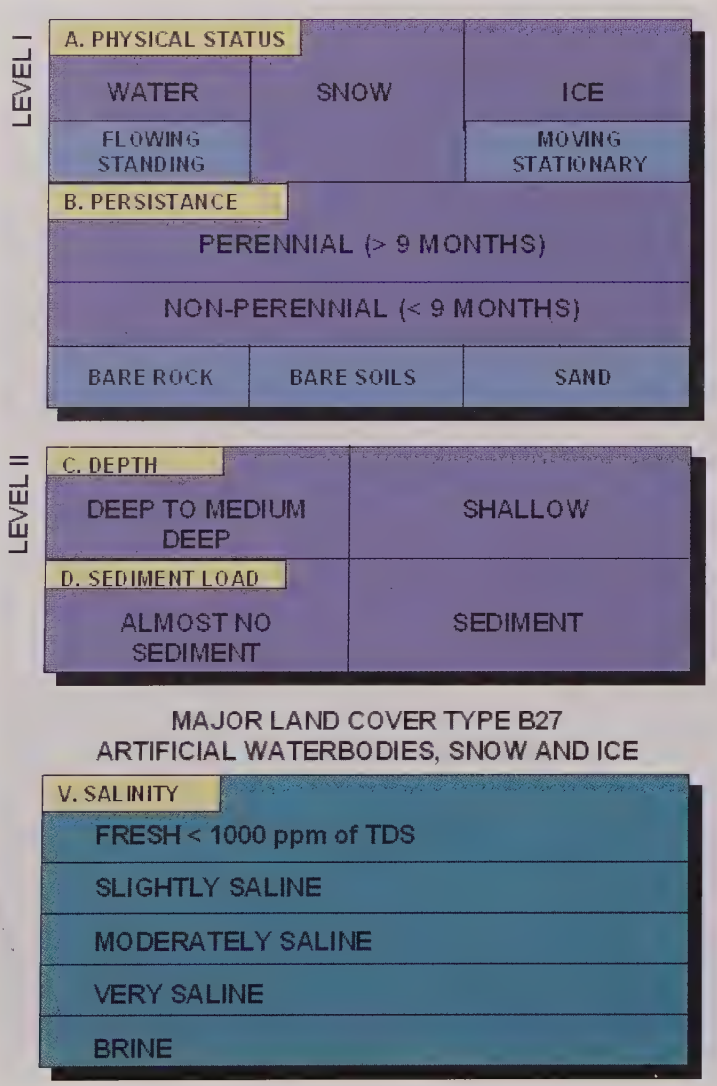
This classifier is only applicable if the total cover of all vegetation in the area is more than 4 percent.



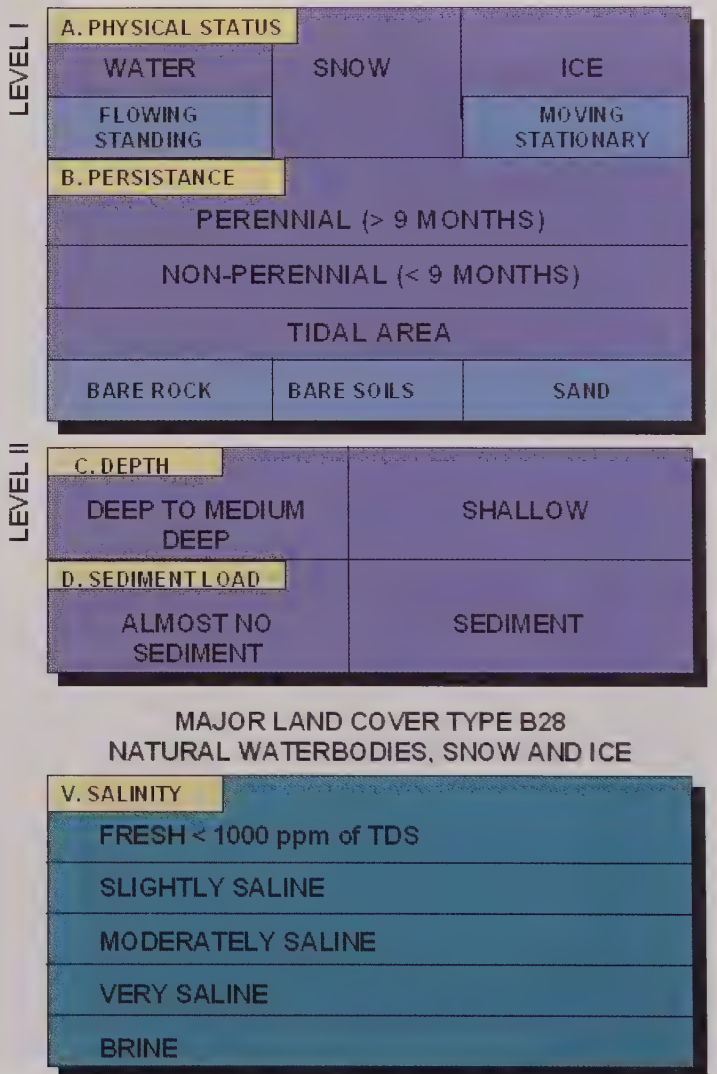
MAJOR LAND COVER TYPE B15
ARTIFICIAL SURFACES
AND
ASSOCIATED AREAS



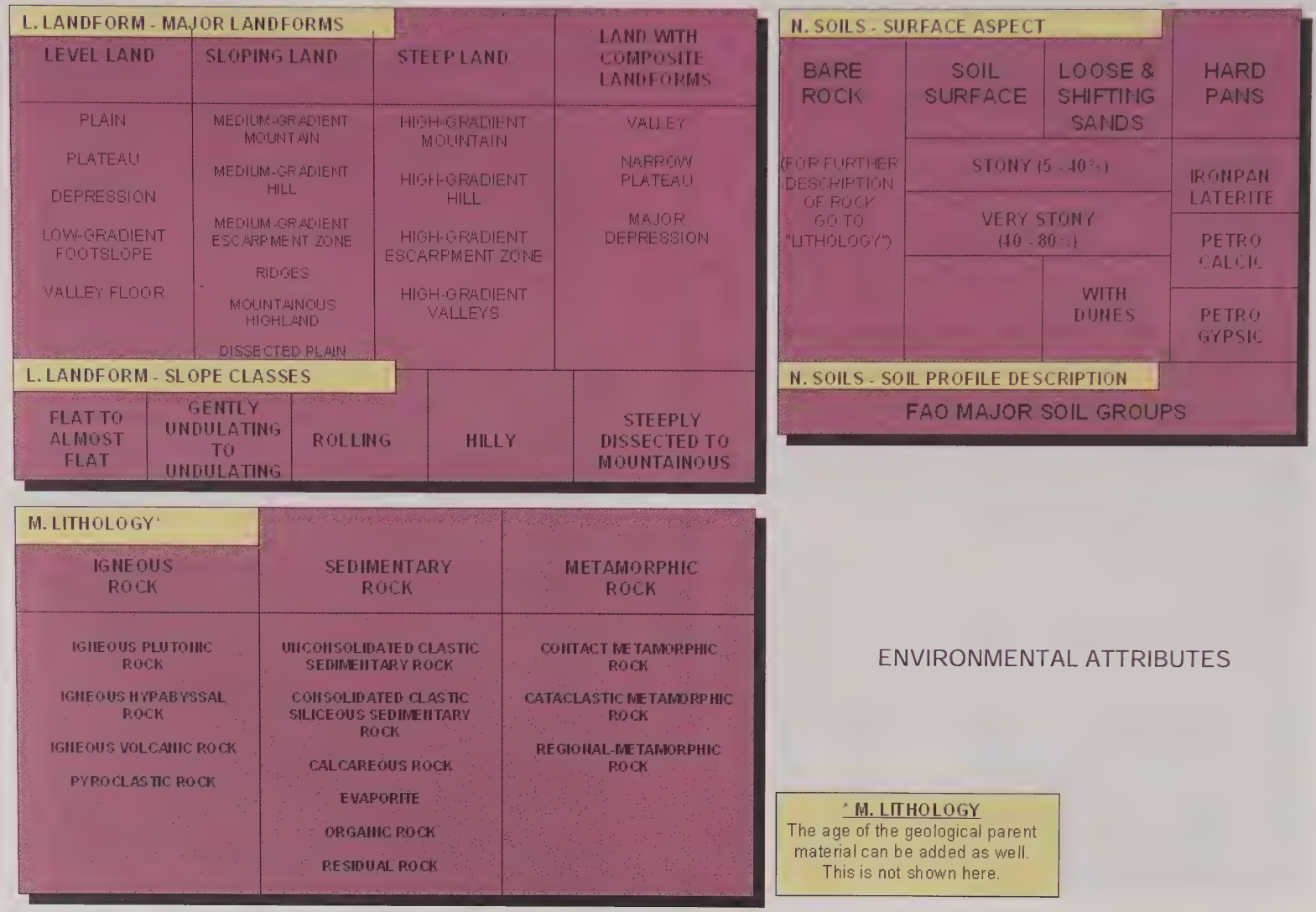
MAJOR LAND COVER TYPE B16
BARE AREAS



MAJOR LAND COVER TYPE B27
ARTIFICIAL WATERBODIES, SNOW AND ICE

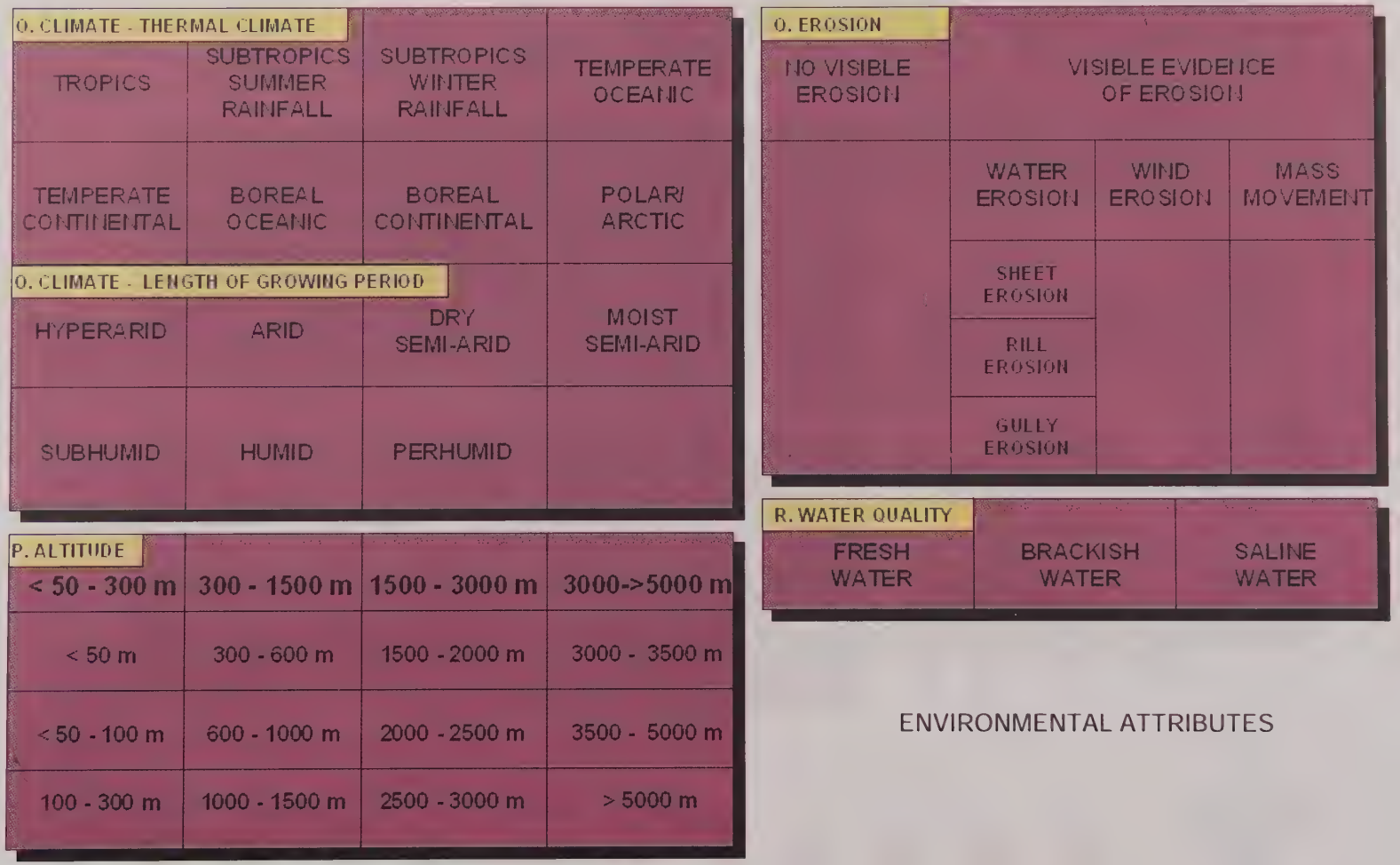


MAJOR LAND COVER TYPE B28
NATURAL WATERBODIES, SNOW AND ICE



ENVIRONMENTAL ATTRIBUTES

* **M. LITHOLOGY**
The age of the geological parent material can be added as well. This is not shown here.



ENVIRONMENTAL ATTRIBUTES

U. SCATTERED VEGETATION *

SCATTERED VEGETATION PRESENT

WOODY	HERBACEOUS		LICHENS/MOSSES	
	FORBS	GRAMINOIDS	LICHENS	MOSSES

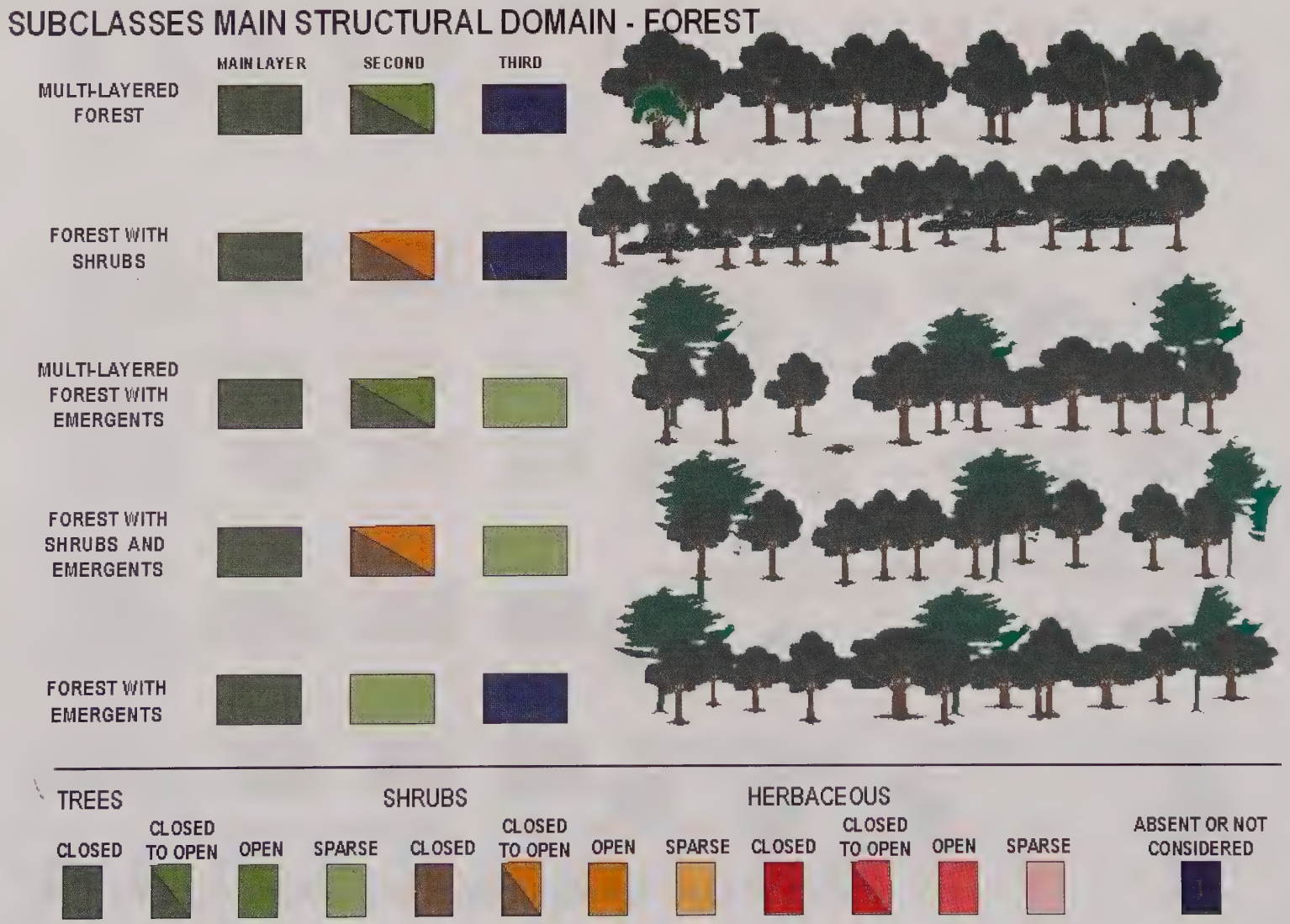
W. CROP COVER/CROP DENSITY

PERMANENT LIFE FORMS (TREES AND SHRUBS)	TEMPORARY LIFE FORMS (HERBACEOUS)
CLOSED > (70 - 60) %	HIGH > 60 %
OPEN (70 - 60) - (20 - 10) %	MEDIUM 60 - 30 %
SPARSE < (20 - 10) %	LOW 30 - 15 %

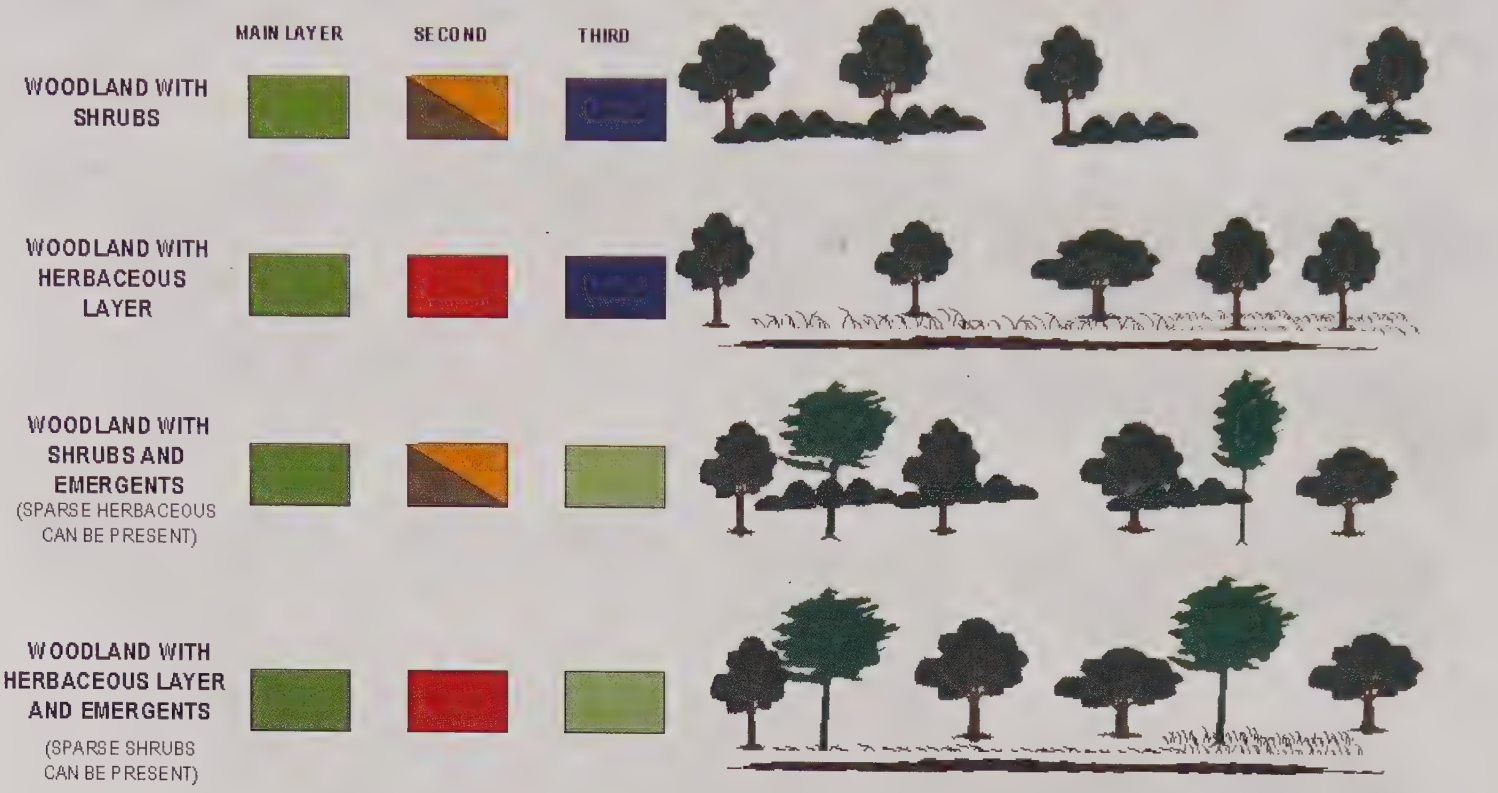
SCATTERED VEGETATION *

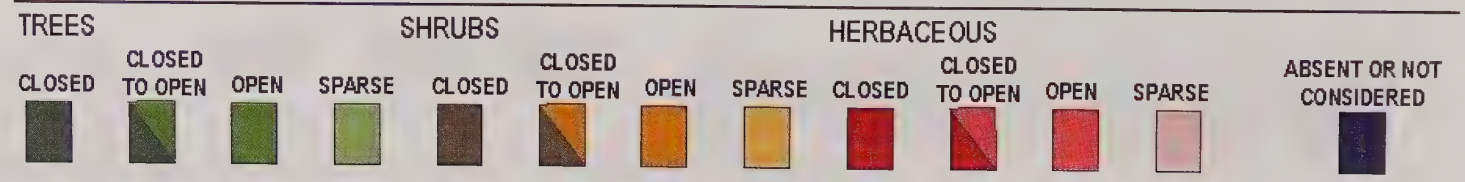
ONLY APPLICABLE FOR MAJOR LAND COVER TYPES OF PRIMARILY NON-VEGETATED AREAS.

ENVIRONMENTAL ATTRIBUTES

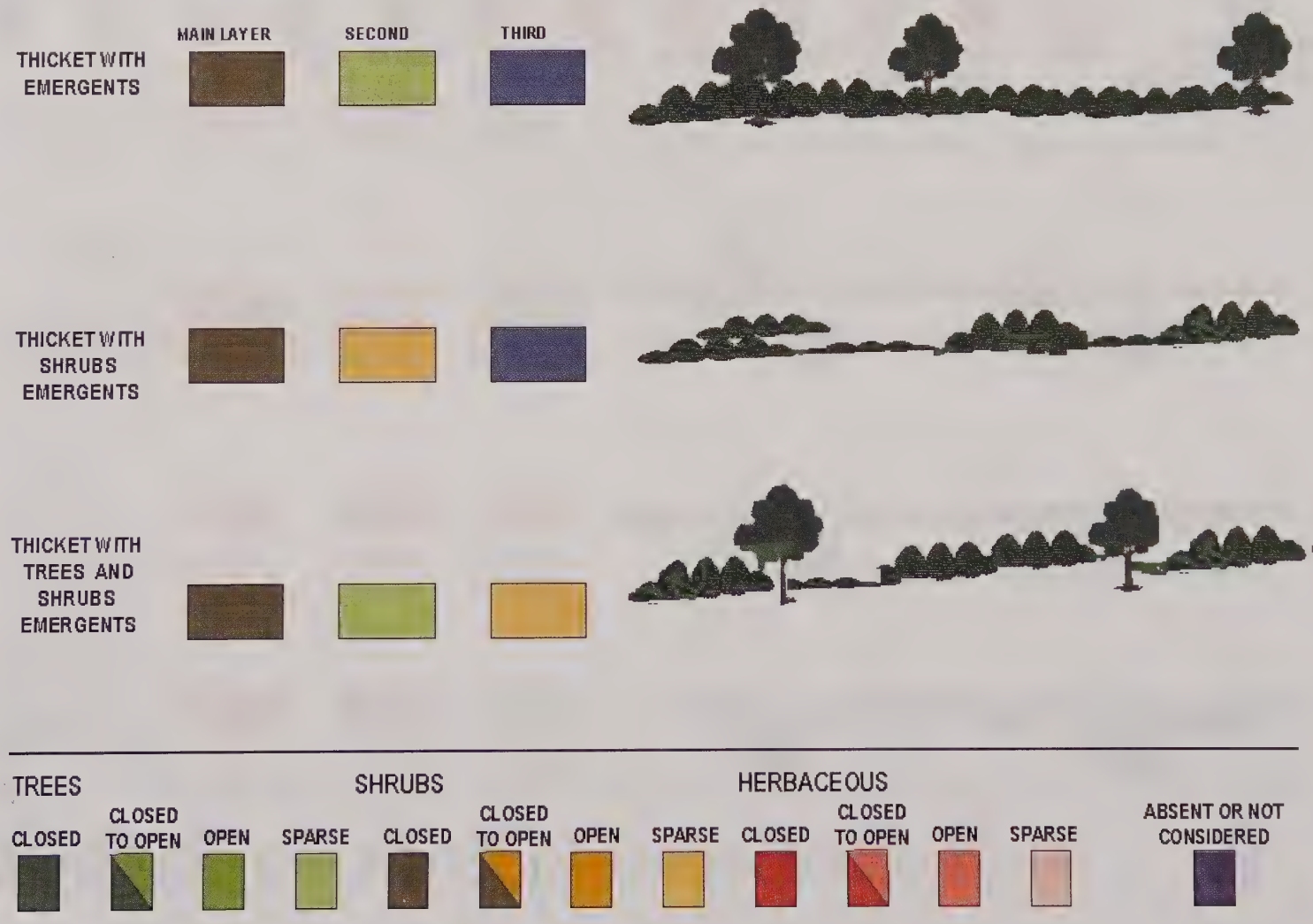

SUBCLASSES MAIN STRUCTURAL DOMAIN - FOREST
MAIN LAYER
SECOND
THIRD
MULTI-LAYERED FOREST
FOREST WITH SHRUBS
MULTI-LAYERED FOREST WITH EMERGENTS
FOREST WITH SHRUBS AND EMERGENTS
FOREST WITH EMERGENTS
TREES
SHRUBS
HERBACEOUS
CLOSED
CLOSED TO OPEN
OPEN
SPARSE
CLOSED
CLOSED TO OPEN
OPEN
SPARSE
CLOSED
CLOSED TO OPEN
OPEN
SPARSE
ABSENT OR NOT CONSIDERED

SUBCLASSES MAIN STRUCTURAL DOMAIN - WOODLAND

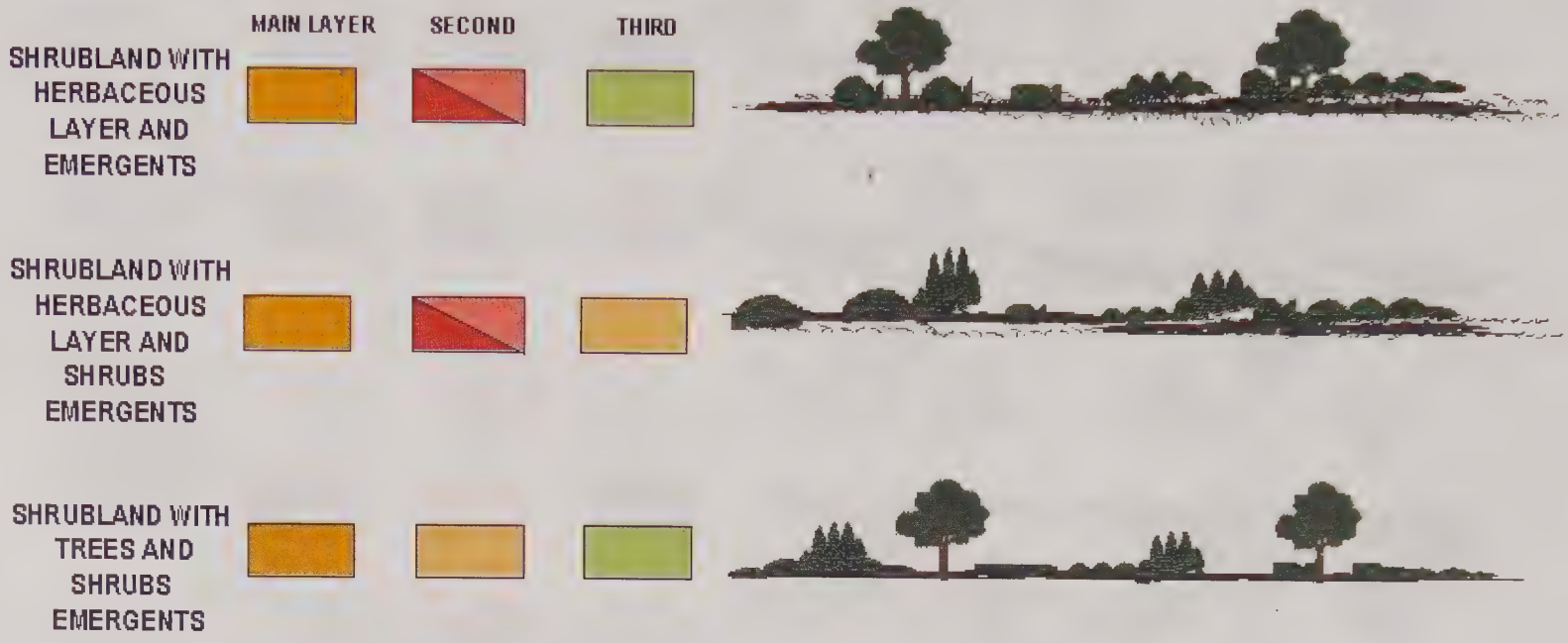




SUBCLASSES MAIN STRUCTURAL DOMAIN - THICKET



SUBCLASSES MAIN STRUCTURAL DOMAIN - SHRUBLAND (1)



SUBCLASSES MAIN STRUCTURAL DOMAIN - SHRUBLAND (2)

SUBCLASSES MAIN STRUCTURAL DOMAIN - GRASSLAND

APPENDIX C - OVERVIEW OF ENVIRONMENTAL ATTRIBUTES OF EACH MAJOR LAND COVER TYPE OF THE CLASSIFICATION SYSTEM

PRIMARILY VEGETATED

A11. CULTIVATED AND MANAGED TERR. AREAS

	Code
I. A. Life Form of the Main Crop	
Trees	A1
Broadleaved	A7
Needleleaved	A8
Evergreen	A9
Deciduous	A10
Shrubs	A2
Broadleaved	A7
Needleleaved	A8
Evergreen	A9
Deciduous	A10
Herbaceous	A3
Graminoids	A4
Non-Graminoids	A5
Urban Vegetated Area(s)	A6
Parks	A11
Parkland	A12
Lawns	A13
B. Spatial Aspect - Field Size	
Large To Medium Sized Field(s)	B1
Large Sized Field(s)	B3
Medium Sized Field(s)	B4
Small Sized Field(s)	B2
B. Spatial Aspect - Field Distribution	
Continuous	B5
Scattered Clustered	B6
Scattered Isolated	B7
II. C. Crop Combination	
Single Crop	C1
Multiple Crop	C2
One Additional Crop	C3
Trees	C5
Shrubs	C6
Herbaceous Terrestrial	C7
Herbaceous Aquatic	C8
Simultaneously	C17
Overlapping	C18
Sequential	C19
Two Additional Crops	C4
Trees	C9
Shrubs	C10
Herbaceous Terrestrial	C11
Herbaceous Aquatic	C12
Simultaneously	C17
Overlapping	C18
Sequential	C19
Trees	C13
Shrubs	C14
Herbaceous Terrestrial	C15
Herbaceous Aquatic	C16
Simultaneously	C17
Overlapping	C18
Sequential	C19
III. D. Cultural Practices - Water Supply	
Rainfed	D1
Postflooding	D2

A12. (SEMI)NATURAL TERR. VEGETATION.

	Code
I. A. Life Form of the Main Strata	
Woody	A1
Trees	A3
Shrubs	A4
Herbaceous	A2
Forbs	A5
Graminoids	A6
Lichens/Mosses	A7
Lichens	A8
Mosses	A9
A. Cover	
Closed (>70-60%)	A10
Open (70-60 - 20-10%)	A11
(70-60 - 40%)	A12
(40 - 20-10%)	A13
Sparse (20-10 - 1%)	A14
(<20-10 - 4%)	A15
Scattered (4 - 1%)	A16
B. Height	
7 - 2m (for Woody)	B1
>30 - 3m (for Trees)	B2
>14m	B5
14-7m	B6
7-3m	B7
5 - 0.3m	B3
5-0.5m	B14
5-3m	B8
3-0.5m	B9
<0.5m	B10
3 - 0.03m	B4
3-0.3m	B15
3-0.8m	B11
0.8-0.3m	B12
0.3-0.03m	B13
C. Spatial Distribution/Macropattern	
Continuous	C1
Fragmented	C2
Striped	C4
Cellular	C5
Parklike Patches	C3
II. D. Leaf Type	
Broadleaved	D1
Needleleaved	D2
Aphyllous	D3
E. Leaf Phenology	
Evergreen	E1
Semi-Evergreen	E4
Deciduous	E2
Semi-Deciduous	E4
Mixed	E3
Mixed (for Forbs/Graminoids)	E5
Annual	E6
Perennial	E7
III. F. Stratification - Second Layer	
Second Layer Absent	F1
Second Layer Present	F2

A24. (SEMI)NATURAL AQUATIC VEGETATION

	Code
I. A. Life Form of the Main Strata	
Woody	A1
Trees	A3
Shrubs	A4
Herbaceous	A2
Forbs	A5
Rooted	A8
Free Floating	A9
Graminoids	A6
Lichens/Mosses	A7
Lichens	A10
Mosses	A11
A. Cover	
Closed (>70-60%)	A12
Open (70-60 - 20-10%)	A13
(70-60 - 40%)	A14
(40 - 20-10%)	A15
Sparse (20-10 - 1%)	A16
(<20-10 - 4%)	A17
Scattered (4 - 1%)	A18
B. Height	
7 - 2m (for Woody)	B1
>30 - 3m (for Trees)	B2
>14m	B5
14-7m	B6
7-3m	B7
5 - 0.3m	B3
5-0.5m	B14
5-3m	B8
3-0.5m	B9
<0.5m	B10
3 - 0.03m	B4
3-0.3m	B15
3-0.8m	B11
0.8-0.3m	B12
0.3-0.03m	B13
II. C. Water Seasonality	
More than 4 Months A Year	C1
Persistent For Whole Day	C4
With Daily Variations	C5
Less than 4 but More than 2 Months/	C2
Waterlogged	C3
III. D. Leaf Type	
Broadleaved	D1
Needleleaved	D2
Aphyllous	D3
E. Leaf Phenology	
Evergreen	E1
Semi-Evergreen	E3
Deciduous	E2
Semi-Deciduous	E3
Mixed	E4
Mixed (for Forbs/Graminoids)	E5
Annual	E6
Perennial	E7
IV. F. Stratification - Second Layer	

PRIMARILY NON-VEGETATED

B15. ARTIFICIAL SURFACES AND ASS. AREAS

	Code
I. A. Surface Aspect	
Built Up	A1
Linear	A3
Roads	A7
Paved	A8
Unpaved	A9
Railways	A10
Comm. Lines/Pipelines	A11
Non-Linear	A4
Industrial a/o Other	A12
High Density	A14
Medium Density	A15
Low density	A16
Urban Areas	A13
High Density	A14
Medium Density	A15
Low density	A16
Non Built Up	A2
Waste Dump Deposits	A5
Extraction Sites	A6
A. BUILT-UP OBJECT	
(scroll list with pre-defined entries)	

B16. BARE AREAS

	Code
I. A. Surface aspect	
Consolidated	A1
Bare Rock a/o Coarse Fragm.	A3
Bare Rock	A7
Gravel/Stones/Boulders	A8
Gravel	A14
Stones	A15
Boulders	A16
Hardpans	A4
Ironpan/Laterite	A9
Petrocalcic	A10
Petrogypsic	A11
Unconsolidated	A2
Bare Soil a/o Other Uncon. Mat.	A5
Stony (5 - 40%)	A12
Very Stony (40 - 80%)	A13
Loose and Shifting Sands	A6
Stony (5 - 40%)	A12
Very Stony (40 - 80%)	A13
II. B. Macropattern - Sands	
Dunes	B1
Barchans	B2
Saturated	B5
Unsaturated	B8
Parabolic Dunes	B3
Saturated	B6
Unsaturated	B9
Longitudinal Dunes	B4
Saturated	B7
Unsaturated	B10
B. Macropattern - Soils	
Gilgai	B11

Irrigated	D3
Surface Irrigation	D4
Sprinkler Irrigation	D5
Drip Irrigation	D6
D. Cult. Practices - Cult. Time Factor	
Shifting Cultivation	D7
Fallow System	D8
Permanent Cultivation	D9
S. CROP TYPE	
Food Crops	S1
Cereals (and Pseudocereals)	S3
Roots and Tubers	S4
Pulses and Vegetables	S5
Fruit and Nuts	S6
Fodder Crops	S7
Beverages and Stimulants	S8
Other	S13
Non-Food Crops	S2
Industrial Crops	S9
Wood/Timber	S10
Other	S14

A23. CULTIVATED AQUATIC AREAS

	Code
I. A. Life Form of the Main Crop	
Graminoids	A1
Non-Graminoids	A2
B. Spatial Aspect - Size	
Large To Medium Sized Field(s)	B1
Large Sized Field(s)	B3
Medium Sized Field(s)	B4
Small Sized Field(s)	B2
B. Spatial Distribution	
Continuous	B5
Scattered Clustered	B6
Scattered Isolated	B7
II. C. Water Seasonality	
Persistent for Whole Day	C1
With Daily Variations	C2
Waterlogged	C3
III. D. Cultural Practices - Fallow period	
Relay Intercropping	D1
Sequential	D2
IV E. Crop Combination	
One Additional Crop	E1
Herbaceous Aquatic	E3
Herbaceous Terrestrial	E4
Two Additional Crops	E2
Herbaceous Aquatic	E5
Herbaceous Terrestrial	E6
Herbaceous Aquatic	E7
Herbaceous Terrestrial	E8
S. CROP TYPE	
Food Crops	S1
Cereals	S3
Fodder Crops	S7
Other	S13
Non-Food Crops	S2
Crops For Biological Filtration	S11
Fibre Crops and Structural Mat.	S12
Other	S14

Woody	F3
Trees	F5
Shrubs	F6
Herbaceous	F4
G. Cover - Second Layer	
Closed To Open	F7
Closed (>70-60%)	F8
Open (70-60 - 20-10%)	F9
Sparse (20-10 5%)	F10
H. Height - Second Layer	
7 - 2m (for Woody)	G1
>30 - 3m	G2
>14m	G5
14-7m	G6
7-3m	G7
5 - 0.3m	G3
5-3m	G8
3-0.5m	G9
<0.5m	G10
3 - 0.03m	G4
3-0.3m	G11
0.3-0.03m	G12
F. Stratification - Third layer	
Third Layer Absent	F1
Third Layer Present	F2
Woody	F3
Trees	F5
Shrubs	F6
Herbaceous	F4
G. Cover - Third Layer	
Closed To Open	F7
Closed (>70-60%)	F8
Open (70-60 - 20-10%)	F9
Sparse (20-10 5%)	F10
H. Height - Third Layer	
7 - 2m (for Woody)	G1
>30 - 3m	G2
>14m	G5
14-7m	G6
7-3m	G7
5 - 0.3m	G3
5-3m	G8
3-0.5m	G9
<0.5m	G10
3 - 0.03m	G4
3-0.3m	G11
0.3-0.03m	G12
T. FLORISTIC ASPECT	
Single Plant Species	T1
Dominant Species	T3
Most Frequent Species	T4
Groups of Plant Species	T2
Statistically Derived Groups	T5
Non-Statistically Derived	T6

Second Layer Absent	F1
Second Layer Present	F2
Woody	F3
Trees	F5
Shrubs	F6
Herbaceous	F4
G. Cover	
Closed To Open	F7
Closed (>70-60%)	F8
Open (70-60 - 20-10%)	F9
Sparse (20-10 5%)	F10
H. Height	
7 - 2m (for Woody)	G1
>30 - 3m	G2
>14m	G5
14-7m	G6
7-3m	G7
5 - 0.3m	G3
5-3m	G8
3-0.5m	G9
<0.5m	G10
3 - 0.03m	G4
3-0.3m	G11
0.3-0.03m	G12
T. FLORISTIC ASPECT	
Single Plant Species	T1
Dominant Species	T3
Most Frequent Species	T4
Groups of Plant Species	T2
Statistically Derived Groups	T5
Non-Statistically Derived	T6

ENVIRONMENTAL ATTRIBUTES FOR EACH MAJOR LAND COVER TYPE

A1: Landform, Lithology, Soil, Climate, Altitude, Erosion and Crop Cover/Density.

A1: Landform, Lithology, Soil, Climate, Altitude and Erosion.

A2: Landform, Lithology, Soil, Climate, Altitude, Erosion and Crop Cover/Density.

A2: Landform, Lithology, Soil, Climate, Altitude, Erosion and Water Quality.

B1: Landform, Climate and Altitude

B1: Landform, Climate, Altitude, Erosion and Scattered Vegetation.

B27/B28: Climate, Altitude and Scattered Vegetation.

Termite Mounds	B12

B27. ARTIFICIAL WATERBODIES, SNOW AND ICE

	Code
I. A. Physical Status	
Water	A1
Flowing	A4
Standing	A5
Snow	A2
Ice	A3
Moving	A6
Stationary	A7
B. Persistence	
Perennial (> 9 Months)	B1
Non-Perennial (< 9 Months)	B2
Surface Aspect: Bare Rock	B3
Surface Aspect: Bare Soil	B4
Surface Aspect: Sand	B5
II. C. Depth	
Deep To Medium	C1
Shallow	C2
D. Sediment Load	
Almost No Sediment	D1
With Sediment	D2
V. SALINITY	
Fresh (<1,000 ppm of TDS)	V1
Slightly Saline	V2
Moderately Saline	V3
Very Brine	V4
Brine	V5

B28. INLAND WATERBODIES, SNOW AND ICE

	Code
I. A. Physical Status	
Water	A1
Flowing	A4
Standing	A5
Snow	A2
Ice	A3
Moving	A6
Stationary	A7
B. Persistence	
Perennial (> 9 Months)	B1
Non-Perennial (< 9 Months)	B2
Surface Aspect: Bare Rock	B4
Surface Aspect: Bare Soil	B5
Surface Aspect: Sand	B6
Tidal Area	B3
Surface Aspect: Bare Rock	B4
Surface Aspect: Bare Soil	B5
Surface Aspect: Sand	B6
II. C. Depth	
Deep To Medium	C1
Shallow	C2
D. Sediment Load	
Almost No Sediment	D1
With Sediment	D2
V. SALINITY	
Fresh (<1,000 ppm of TDS)	V1
Slightly Saline	V2
Moderately Saline	V3
Very Brine	V4
Brine	V5

APPENDIX C - OVERVIEW OF ENVIRONMENTAL ATTRIBUTES OF EACH MAJOR LAND COVER TYPE OF THE CLASSIFICATION SYSTEM

ENVIRONMENTAL ATTRIBUTES

L. LANDFORM *	Code
Level Land	L1
Sloping Land	L2
Steep Land	L3
Land With Composite Landforms	L4

M. LITHOLOGY *	Code
Igneous rock	M100
Igneous plutonic rock	M110
Granite	M111
Granodiorite	M112
Quartz diorite	M113
Syenite	M114
Monzonite	M115
Diorite	M116
Gabbro	M117
Foidic plutonic rock	M118
Ultramafic plutonic rock	M119
Igneous hypabyssal rock	M120
Aplite	M121
Pegmatite	M122
Porphyry	M123
Dolerite/diabase	M124
Igneous volcanic rock	M130
Rhyolite	M131
Dacite	M132
Trachyte	M133
Latite	M134
Andesite	M135
Basalt	M136
Phonolite	M137
Tephrite	M138
Pyroclastic rock	M140
Ash	M141
Lapilli	M142
Scoria	M143
Tuff	M144
Ignimbrite	M145
Lahar	M146
Agglomerate	M147
Other Igneous rock	M199
Sedimentary rock	M200
Unconsolidated clastic sed. rock	M210
Clay	M211
Silt	M212
Sand	M213
Gravel	M214
Loess	M215
Loam	M216
Colluvium	M217
Shells	M218
Cons. clastic siliceous sed. rock	M220
Mudstone	M221
Siltstone	M222
Shale	M223
Quartzarenite	M224

(Continued in next column)

M. LITHOLOGY - Continued	Code
Lithic arenite	M225
Feldspathic arenite/arkose	M226
Graywacke	M227
Conglomerate	M228
Breccia	M229
Calcareous rock	M230
Marl	M231
Calcilutite	M232
Calcarenite	M233
Calcirudite	M234
Algal/reefal limestone	M235
Travertine	M236
Tufa	M237
Dolomite	M238
Evaporite	M240
Gypsum	M241
Halite	M242
Organic rock	M250
Peat	M251
Lignite	M252
Coal	M253
Tar	M254
Residual rock	M260
Laterite	M261
Bauxite	M262
Kaolin	M263
Other Sedimentary rock	M299
Metamorphic rock	M300
Contact metamorphic rock	M310
Hornfels	M311
Spotted slate	M312
Skarn	M313
Cataclastic metamorphic rock	M320
Cataclastic breccia	M321
Mylonite	M322
Regional-metamorphic rock	M330
Slate	M331
Schist	M332
Gneiss	M333
Migmatite	M334
Granulite	M335
Eclogite	M336
Quartzite	M337
Marble	M338
Serpentinite	M339
Other Metamorphic rock	M399
M. LITHOLOGY - AGE GEOL. PARENT MAT.	
Quaternary	M400
Holocene	M410
Pleistocene	M420
Late Pleistocene	M421
Middle Pleistocene	M422
Early Pleistocene	M423
Tertiary	M500
Pliocene	M510
Miocene	M520
Oligocene	M530

M. LITHOLOGY - Continued	Code
Eocene	M540
Paleocene	M550
Mesozoic	M600
Cretaceous	M610
Jurassic	M620
Triassic	M630
Paleozoic	M700
Permian	M710
Carboniferous	M720
Devonian	M730
Silurian	M740
Ordovician	M750
Cambrian	M760
Precambrian	M800

N. SOIL - SURFACE ASPECT	Code
Bare Rock	N1
Soil Surface	N2
Stony (5 - 40%)	N5
Very Stony (40 - 80%)	N6
Loose and Shifting Sands	N3
Stony (5 - 40%)	N5
With Dunes	N7
Hardpans	N4
Ironpan/Laterite	N8
Petrocalcic	N9
Petrogypsic	N10
Hardened Plinthite	N11
N. SOIL - SUBSURFACE ASPECT	
FAO's Major Soil Groups *	N12

O. CLIMATE *	Code
Thermal Climate:	
Tropics	O1
Subtropics - Summer Rainfall	O2
Subtropics - Winter Rainfall	O3
Temperate Oceanic	O4
Temperate Continental	O5
Boreal Oceanic	O6
Boreal Continental	O7
Polar Arctic	O8
Moisture Determined LGP:	
Hyperarid	O9
Arid	O10
Dry Semi-Arid	O11
Moist Semi-Arid	O12
Subhumid	O13
Humid	O14
Perhumid	O15

*** REFERENCES:**

Landform: UNEP/ISSS/ISRIC/FAO, 1995.
Lithology: provided by S.B. Kroonenberg, 1998.
Climate: De Pauw, E., Nachtergaele, F.O. & J. Antoine,1995.
Soils: FAO/Unesco/ISRIC, 1990; FAO, 1993.

P. ALTITUDE *
< 50 - 300 m
< 50 m
50 - 100 m
100 - 300 m
300 - 1500 m
300 - 600 m
600 - 1000 m
1000 - 1500 m
1500 - 3000 m
1500 - 2000 m
2000 - 2500 m
2500 - 3000 m
3000 - >5000 m
3000 - 3500 m
3500 - 5000 m
> 5000 m

Q. EROSION
No Visible Erosion
Visible Evidence of Erosion
Water Erosion
Sheet
Rill
Gully
Wind Erosion
Mass Movement

R. WATER QUALITY
Fresh Water
Brackish Water
Saline Water

U. SCATTERED VEGETATION
Scattered Vegetation Present
Woody
Herbaceous
Forbs
Graminoids
Lichens/Mosses
Lichens
Mosses

W. CROP COVER/CROP DENSITY
Permanent Life Forms:
Closed Cover >(70-60)%
Open Cover (70-60) - (20-10)%
Sparse Cover <(20-10)%
Plantations(s)
Orchard(s)
Temporary Life Forms:
High Crop Density (> 60%)
Medium Crop Density (60 - 3
Low Crop Density (30 - 15%)

APPENDIX D.

TRANSLATOR MODULE – COMPARISON AND SIMILARITY ASSESSMENT VALUES

Comparison of classifiers is based first on the comparability of the classifier, followed by comparison of the selected options of the specific classifier. Thus, *Life Form* of vegetation can be compared with *Life Form* of cultivated areas. If the option selected for the dominant Life Form of vegetation is *Trees* and a *Tree Crop* has been specified for the cultivated areas, the comparison will generate 100 percent similarity. If a *Shrub Crop* has been specified, the comparison will result in 0 percent similarity. However, not all comparisons of classifiers will generate 100 percent similarity or 0 percent similarity. There are also a number of cases where the value is set to 50 percent. These cases are discussed below:

1. Some classifier options contain different levels presented in different rows (e.g., in Life Form *Woody* above *Trees* and *Shrubs* as shown in Figure 14). The option of the general level can be compared with the options of the more detailed level but such a comparison will generate a similarity of 50 percent (e.g., *Woody* comprises both *Trees* and *Shrubs*; comparison of *Woody* with *Trees* will lead to a similarity value that indicates that they are only partially similar).

2. Some classifier options contain two characteristics (e.g., the *Life Form* options *Herbaceous Terrestrial* and *Herbaceous Aquatic* in A11 and A23). When comparing such options one may wonder which characteristic is being compared and if both characteristics have the same weight in the comparison. In principle, both characteristics are being compared with equal weights (e.g., in the example above, *Herbaceous Terrestrial* compared to A12 *Herbaceous* will generate a 100 percent similarity value because they contain the same life form as well as an identical environment, whereas comparison with A24 *Herbaceous* will generate 50 percent because of the different environments in which the herbaceous life form is found).

3. Some classifier options cannot be compared because they are linked to dominance (e.g., in A12 and A24, the life forms are linked to description of a certain vegetation layer, and in A11 and A23 the life forms are linked to the description in relation to cover or economic revenue). The *Life Form* of the main layer, that is the first layer described, cannot be compared to a life form of a second and third layer, or to a life form of an additional crop.

4. Vegetation stratification and crop layering cannot be compared beyond description of the existence of a single layer. This condition is set because the occurrence of multiple crops does not imply that these crops occur in different layers. Therefore, only the option *Single Layer* can be compared with *Single Crop* (Monoculture).

The tables on the following pages show the similarity values of the classifiers and modifiers.

Comparison of Classifiers and Modifiers (100 percent similar)
- Primarily Vegetated Areas -

A11	A12	A23	A24
≠ [1]	A1. Woody	≠	A1. Woody
A1. Tree Crop	A3. Trees	≠	A3. Trees
A2. Shrub Crop	A4. Shrubs	≠	A4. Shrubs
A3. Herbaceous Crop	A2. Herbaceous	≠	A2. Herbaceous
A4. Graminoid Crop	A6. Graminoids	A1. Graminoid Crop	A6. Graminoids
A5. Non-Graminoid Crop	A5. Forbs	A2. Non-Graminoid Crop	A5. Forbs
≠	A7. Lichens/Mosses	≠	A7. Lichens/Mosses
≠	A8. Lichens	≠	A10. Lichens
≠	A9. Mosses	≠	A11. Mosses
≠	≠	≠	A8. Rooted
≠	≠	≠	A9. Free Floating
≠	A10. Closed	≠	A12. Closed
≠	A11. Open	≠	A13. Open
≠	A12. 65 – 40%	≠	A14. 65 – 40%
≠	A13. 40 – 15%	≠	A15. 40 – 15%
≠	A14. Sparse	≠	A16. Sparse
≠	A15. Sparse (15 – 4%)	≠	A17. Sparse (15 – 4%)
≠	A16. Scattered (4 – 1%)	≠	A18. Scattered (4 - 1%)
≠	B1. 7 – 2 m	≠	B1. 7 – 2 m
≠	B2. >30 – 3 m	≠	B2. >30 – 3 m
≠	B3. 5 – 0.3 m	≠	B3. 5 – 0.3 m
≠	B4. 3 – 0.03 m	≠	B4. 3 – 0.03 m
≠	B5. High	≠	B5. High
≠	B6. Medium High	≠	B6. Medium High
≠	B7. Low	≠	B7. Low
≠	B8. High	≠	B8. High
≠	B9. Medium High	≠	B9. Medium High
≠	B10. Dwarf	≠	B10. Dwarf
≠	B11. Tall	≠	B11. Tall
≠	B12. Medium Tall	≠	B12. Medium Tall
≠	B13. Short	≠	B13. Short
≠	B14. Medium to High	≠	B14. Medium to High
≠	B15. Medium to Tall	≠	B15. Medium to Tall
≠	C1. Continuous	≠	≠
≠	C2. Fragmented	≠	≠
≠	C3. Parklike Patches	≠	≠
≠	C4. (Striped)	≠	≠
≠	C5. (Cellular)	≠	≠
A6. Urban Vegetated Areas	≠	≠	≠
A7. Broadleaved	D1. Broadleaved	≠	D1. Broadleaved
A8. Needleleaved	D2. Needleleaved	≠	D2. Needleleaved
≠	D3. Aphyllous	≠	D3. Aphyllous
A9. Evergreen	E1. Evergreen	≠	E1. Evergreen
A10. Deciduous	E2. Deciduous	≠	E2. Deciduous
≠	E3. Mixed	≠	E4. Mixed
≠	E4. Semi-	≠	E3. Semi-
≠	E5. Mixed	≠	E5. Mixed
≠	E6. Perennial	≠	E6. Perennial
≠	E7. Annual	≠	E7. Annual
A11. /Parks	≠	≠	≠
A11. /Parkland	≠	≠	≠
A13. /Lawns	≠	≠	≠
B1. Large-to-Medium Sized Fields	≠	B1. Large-to-Medium Sized Fields	≠
B2. Small-Sized Fields	≠	B2. Small-Sized Fields	≠

1. ≠ means that comparison is impossible.

Comparison of Classifiers and Modifiers (100 percent similar)
- Primarily Vegetated Areas -

A11	A12	A23	A24
B3. Large-Sized Fields	≠	B3. Large-Sized Fields	≠
B4. Medium-Sized Fields	≠	B4. Medium-Sized Fields	≠
B5. Continuous	≠	B5. Continuous	≠
B6. Scattered Clustered	≠	B6. Scattered Clustered	≠
B7. Scattered Isolated	≠	B7. Scattered Isolated	≠
≠	≠	C1. Permanently Flooded	C1. Permanently Flooded
≠	≠	C2. With Daily Variations	C5. With Daily Variations
≠	≠	C3. Waterlogged Soil	C3. Waterlogged Soil
≠	≠	≠	C2. Temporarily Flooded
≠	≠	C1. Permanently Flooded	C4. Persistent for Whole Day
C1. Single Crop	F1. Single Layer	≠	F1. Single Layer
≠	F2. Second and/or Third Layer	≠	F2. Second Layer
≠	F3. Woody	≠	F3. Woody
C2. Multiple Crop	≠	≠	≠
C3. One Additional Crop	≠	E1. One Additional Crop	≠
C4. Two Additional Crops	≠	E2. Two Additional Crops	≠
C5. Tree Crop (Additional Crop)	F5. Trees	≠	F5. Trees
C6. Shrub Crop (Additional Crop)	F6. Shrubs	≠	F6. Shrubs
C7. Herbaceous Terrestrial (Additional Crop)	F4. Herbaceous	E4. Herbaceous Terrestrial (Additional Crop)	≠
C8. Herbaceous Aquatic (Additional Crop)	≠	E3. Herbaceous Aquatic (Additional Crop)	F4. Herbaceous
C9. Tree Crop (Additional Crop)	F5. Trees	≠	F5. Trees
C10. Shrub Crop (Additional Crop)	F6. Shrubs	≠	F6. Shrubs
C11. Herbaceous Terrestrial (Additional Crop)	F4. Herbaceous	E6. Herbaceous Terrestrial (Additional Crop)	≠
C12. Herbaceous Aquatic (Second Additional Crop)	≠	E5. Herbaceous Aquatic (Additional Crop)	F4. Herbaceous
C13. Tree Crop (Second Additional Crop)	F5. Trees	≠	F5. Trees
C14. Shrub Crop (Second Additional Crop)	F6. Shrubs	≠	F6. Shrubs
C15. Herbaceous Terrestrial (Second Additional Crop)	F4. Herbaceous	E8. Herbaceous Terrestrial (Second Additional Crop)	≠
C16. Herbaceous Aquatic (Second Additional Crop)	≠	E7. Herbaceous Aquatic (Second Additional Crop)	F4. Herbaceous
≠	F7. Closed To Open	≠	F7. Closed To Open
≠	F8. Closed	≠	F8. Closed
≠	F9. Open	≠	F9. Open
≠	F10. Sparse	≠	F10. Sparse
C17. With Simultaneous Period	≠	≠	≠
C18. With Overlapping Period	≠	D1. Relay Intercropping	≠
C19. Sequential Period	≠	D2. Sequential	≠
≠	G1. 7 – 2 m	≠	G1. 7 – 2 m
≠	G2. >30 – 3 m	≠	G2. >30 – 3 m
≠	G3. 5 – 0.3 m	≠	G3. 5 – 0.3 m
≠	G4. 3 – 0.03 m	≠	G4. 3 – 0.03 m
≠	G5. High	≠	G5. High
≠	G6. Medium High	≠	G6. Medium High
≠	G7. Low	≠	G7. Low
≠	G8. High	≠	G8. High
≠	G9. Medium High	≠	G9. Medium High
≠	G10. Dwarf	≠	G10. Dwarf
≠	G11. Medium to Tall	≠	G11. Medium to Tall

Comparison of Classifiers and Modifiers (100 percent similar) - Primarily Vegetated Areas -			
A11	**A12**	**A23**	**A24**
≠	G12. Short	≠	G12. Short
D1. Rainfed Cultivation	≠	≠	≠
D2. Post Flooding Cultivation	≠	≠	≠
D3. Irrigated	≠	≠	≠
D4. Surface Irrigated	≠	≠	≠
D5. Sprinkler Irrigated	≠	≠	≠
D6. Drip Irrigated	≠	≠	≠
D7. Shifting Cultivation	≠	≠	≠
D8. Fallow System	≠	≠	≠
D9. Permanently Cropped	≠	≠	≠

Comparison of Classifiers and Modifiers (100 percent similar) - Primarily Non-Vegetated Areas [1] -	
B27	**B28**
A1. Artificial Waterbodies	A1. Natural Waterbodies
A2. Artificial Snow	A2. Snow
A3. Artificial Ice	A3. Ice
A4. (Flowing)	A4. (Flowing)
A5. (Standing)	A5. (Standing)
A6. (Moving)	A6. (Moving)
A7. (Stationary)	A7. (Stationary)
B1. Perennial	B1. Perennial
B2. Non-Perennial	B2. Non-Perennial/Seasonal
≠	B3. Tidal
B3. (Surface Aspect: Bare Rock)	B4. (Surface Aspect: Bare Rock)
B4. (Surface Aspect: Bare Soil)	B5. (Surface Aspect: Bare Soil)
B5. (Surface Aspect: Sand)	B6. (Surface Aspect: Sand)
C1. Deep To Medium Deep	C1. Deep To Medium Deep
C2. Shallow	C2. Shallow
D1. Clear	D1. Clear
D2. Turbid	D2. Turbid

Note: (1) The major land cover types B15 and B16 cannot be compared to any of the other major land cover types.

Comparison of Classifiers and Modifiers (50 percent similar)
- Primarily Vegetated Areas -

A11		A12		A11		A23	
A1.	Tree Crop	A1.	Woody	A3.	Herbaceous Crop	A1.	Graminoid Crop
A2.	Shrub Crop					A2.	Non-Graminoid Crop
A3.	Herbaceous Crop	A5.	Forbs	C7.	Herbaceous Terrestrial (Additional Crop)	E3.	Herbaceous Aquatic (Additional Crop)
		A6.	Graminoids			E5.	Herbaceous Aquatic (Additional Crop)
A4.	Graminoid Crop	A2.	Herbaceous			E7.	Herbaceous Aquatic (Second Additional Crop)
A5.	Non-Graminoid Crop			C8.	Herbaceous Aquatic (Additional Crop)	E4.	Herbaceous Terrestrial (Additional Crop)
A11.	/Parks	A1.	Woody			E6.	Herbaceous Terrestrial (Additional Crop)
		A3.	Trees			E8.	Herbaceous Terrestrial (Second Additional Crop)
A12.	/Parklands	A3.	Trees	C11.	Herbaceous Terrestrial (Additional Crop)	E3.	Herbaceous Aquatic (Additional Crop)
		A4.	Shrubs			E5.	Herbaceous Aquatic (Additional Crop)
A13.	/Lawns	A2.	Herbaceous			E7.	Herbaceous Aquatic (Second Additional Crop)
		A6.	Graminoids	C12.	Herbaceous Aquatic (Additional Crop)	E4.	Herbaceous Terrestrial (Additional Crop)
C5.	Tree Crop (Additional Crop)	F3.	Woody			E6.	Herbaceous Terrestrial (Additional Crop)
C6.	Shrub Crop (Additional Crop)					E8.	Herbaceous Terrestrial (Second Additional Crop)
C8.	Herbaceous Aquatic (Additional Crop)	F4.	Herbaceous	C15.	Herbaceous Terrestrial (Second Additional Crop)	E3.	Herbaceous Aquatic (Additional Crop)
C9.	Tree Crop (Additional Crop)	F3.	Woody			E5.	Herbaceous Aquatic (Additional Crop)
C10.	Shrub Crop (Additional Crop)					E7.	Herbaceous Aquatic (Second Additional Crop)
C12.	Herbaceous Aquatic (Additional Crop)	F4.	Herbaceous	C16.	Herbaceous Aquatic (Second Additional Crop)	E4.	Herbaceous Terrestrial (Additional Crop)
C13.	Tree Crop (Second Additional Crop)	F3.	Woody			E6.	Herbaceous Terrestrial (Additional Crop)
C14.	Shrub Crop (Second Additional Crop)					E8.	Herbaceous Terrestrial (Second Additional Crop)
C16.	Herbaceous Aquatic (Second Additional crop)	F4.	Herbaceous				

Comparison of Classifiers and Modifiers (50 percent similar) (continued)
- Primarily Vegetated Areas -

A11	A24	A12	A23
A1. Tree Crop	A1. Woody	A2. Herbaceous	A1. Graminoid Crop
A2. Shrub Crop			A2. Non-Graminoid Crop
A3. Herbaceous Crop	A5. Forbs	F4. Herbaceous	E3. Herbaceous Aquatic (Additional Crop)
	A6. Graminoids		E5. Herbaceous Aquatic (Additional Crop)
A4. Graminoid Crop	A2. Herbaceous		E7. Herbaceous Aquatic (Second Additional Crop)
A5. Non-Graminoid Crop			
C5. Tree Crop (Additional Crop)	F3. Woody		
C6. Shrub Crop (Additional Crop)			
C7. Herbaceous Terrestrial (Additional Crop)	F4. Herbaceous		
C9. Tree Crop (Additional Crop)	F3. Woody		
C10. Shrub Crop (Additional Crop)			
C11. Herbaceous Terrestrial (Additional Crop)	F4. Herbaceous		
C13. Tree Crop (Second Additional Crop)	F3. Woody		
C14. Shrub Crop (Second Additional Crop)			
C15. Herbaceous Terrestrial (Second Additional Crop)	F4. Herbaceous		

Comparison of Classifiers and Modifiers (50 percent similar)
- Primarily Vegetated Areas -

A12	A24	A23	A24
A1. Woody	A3. Trees	A1. Graminoid Crop	A2. Herbaceous
	A4. Shrubs	A2. Non-Graminoid Crop	
A3. Trees	A1. Woody	E4. Herbaceous Terrestrial (Additional Crop)	F4. Herbaceous
A4. Shrubs		E6. Herbaceous Terrestrial (Additional Crop)	
A2. Herbaceous	A5. Forbs	E8. Herbaceous Terrestrial (Second Additional Crop)	
	A6. Graminoids		
A5. Forbs	A2. Herbaceous		
A6. Graminoids			
A7. Lichens/Mosses	A10. Lichens		
	A11. Mosses		
A8. Lichens	A7. Lichens/Mosses		
A9. Mosses			

APPENDIX E.

LCCS SOFTWARE APPLICATION – STAFF

Staff	Activities	Period
Antonio Di Gregorio	Overall concept development Rules and conditions for (Semi) Natural Vegetation Design of software modules and functions Overall coordination of implementation Anomaly tracking and resolution	March 1996 – December 1999
Louisa J.M. Jansen	Additional concept development Coordination of implementation Classifier database development and updating *Standard Descriptions* database updating Compilation of *Help* files Anomaly tracking and resolution	March 1996 – December 1999
Luca Morandini	Upgrading software application to Access 97 Re-programming *Legend Module* Re-programming conditions *Classification Module* Anomaly tracking and resolution	January – December 1999
Antonio Martucci	Programming *Field Data Module* [1] Programming *Translator Module* [1] Creation of modifier databases	August – December 1996
Wolfgang Prante	Programming *Classification Module* [1] Programming *Legend Module* [1]	May 1996 – December 1998
Keya Choudhury	Compilation and editing of *Help* terminology Creation of *Standard Descriptions*	August 1996 – January 1997

Notes: 1. Programmed in Access version 2.0.

This publication presents a new concept of land cover classification which uses a set of independent diagnostic criteria, the so-called classifiers, rather than being nomenclature based. This approach allows correlation with existing classifications and legends so the system could serve as an internationally agreed reference base for land cover. The methodology is applicable at any scale and is comprehensive in the sense that any land cover identified anywhere in the world can be readily accommodated. The rearrangement of the land cover classes, based on regrouping of the used classifiers, facilitates the extensive use of the outputs by a wide variety of end-users. The Land Cover Classification System (LCCS) has been designed with two main phases: an initial dichotomous phase, in which eight major land cover types are defined, followed by a subsequent modular-hierarchical phase, in which land cover classes are created by the combination of sets of predefined classifiers tailored to each major land cover type in order to use the most appropriate classifiers and to reduce the likelihood of impractical combinations of classifiers. A software program has been developed to assist in land cover interpretation, thus standardizing this process and contributing to its consistency. Despite the huge number of classes that can be generated, the user deals with only one classifier at a time and a land cover class is built up by a stepwise selection in which a number of classifiers are aggregated to derive the class. The software contains four modules comprising classification, legend, storage of field data and translation/correlation of classes at the class level or at the level of the classifiers. It also contains a glossary with definitions of all terms used.

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